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Factors Affecting Survival of Fire Injured Trees: A Rating System For Determining Relative Probability of Survival of Conifers in the Blue and Wallowa Mountains

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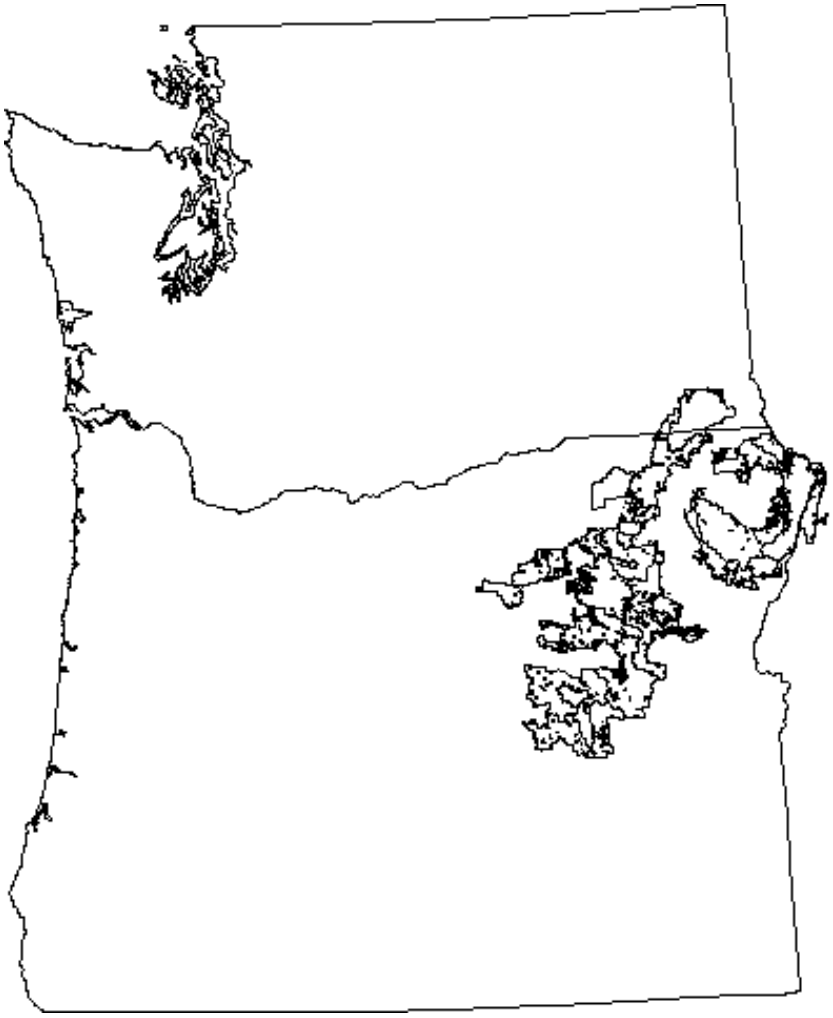

Fire-damaged Ponderosa Pines on The Emigrant Creek Ranger District, Malheur National Forest.

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Introduction

The marking of trees for salvage following wildfire is often difficult and controversial owing to the varied and complex factors governing the survival of fire injured trees. Numerous factors often interact to determine the fate of trees following wildfire, including, but not limited to age, size, crown ratio, bark thickness, and other fire-resistance characteristics of the affected tree species; stand density, fuel loads, season of fire, and growing site quality characteristics that influence the intensity and duration of the fire, and degree of damage to trees; and insect populations and disease status within affected stands.

In addition, the Forest Service must balance various management directions as to the appropriate management for fire-damaged stands and trees. The agency has an obligation to recoup public funds spent on establishing, growing, and managing commercial timber stands damaged by wildfire. The agency also has an obligation to protect sensitive habitats and restore damaged ecosystems following wildfire. Resource managers must balance the need to remove damaged trees while still merchantable with the need to protect legacy habitats. They must protect residual stands from future wildfires that may re-burn the area if the fire created an increase in fuels. Managers also must weigh the potential harm to post-fire residual forests from secondary insects.

Given that insect attack of fire-injured trees are often a concern following wildfire, the wildfire season of 2002 prompted requests from National Forest offices for help from the Blue Mountains Pest Management Service Center in determining the survival potential of these trees. An earlier effort (Scott and others 1996) developed preliminary burn severity guidelines to assess relative risk of tree mortality from insects and/or fire. In many instances over the past half-decade, Ranger Districts used that information to develop specific salvage-marking guidelines. Since that time, more information on fire effects has become available in the published literature, mortality trends associated with measured conditions of fire-injury have been observed from formal fire monitoring plots on numerous wildfires in the Blue Mountains, and tree mortality probability models have been refined and become more widely available.

Accordingly, to provide the National Forests with information to aid in their decision-making process regarding survival of fire-injured timber resources, we herein provide a standardized rating system for determining three relative survival decision classes describing **High**, **Moderate**, and **Low** probability of

tree survival following wildfire. By defining the ranges for these class distinctions, we assume that roughly 50% of the trees falling within the "Moderate" survival class will survive and 50% will not.

Our intent is for these procedures to provide a basis upon which Districts may further develop their own specific marking guidelines. By providing these procedures we are not prescribing marking guidelines. It is possible for Forests to adopt this system, combined with other criteria for marking trees for salvage. The rating system incorporates the current state of the science and should be adequate for separating fire-injured trees into the three broad survival classes indicated above.

Methodology and Development

We have standardized these procedures for tree species, and size or age of tree as appropriate, and for various other factors so that the procedures may be applied on any wildfire on any National Forest in the Blue Mountains, now and in the future. Moreover, it should be possible to adapt these procedures to determine relative survival of similar conifer species injured by fire occurring on other National Forests outside of the Blue and Wallowa Mountains. While we sought to keep the procedure as simple to use as possible, we found that consideration of a variety of important factors to survival of trees added unavoidable complexity to the system. We do not believe a less complex system would be adequate to address all the concerns that were presented to us by the Forests. While every effort was made to ensure a reliable rating system, this rating system has not been calibrated nor field validated. This work will begin early in 2003.

We designed the system to characterize what we feel to be the most important, and easiest obtained, factors affecting the survival of fire-injured conifers by species (and age or size in some cases) here in the Blue and Wallowa Mountains of northeast Oregon and southeast Washington. These factors have come from a thorough review of the published literature (most of it weighted heavily to prescribed fire effects), tree mortality model outputs, and observations and data from our most recent fire reviews and monitoring plots.

The following Rating system can be used directly for field reconnaissance purposes. The system requires rating **individual trees** over areas of interest or concern on the fire. To use the system the reader works through each Part consecutively (Parts A, B, and C), selecting the appropriate rating value given in parentheses adjacent to each factor, and recording the rating value in the right-hand "Rating" column. The "Rating Score" for each part is subtotaled at the end of each part. The "Composite Rating Score" is obtained by adding together the subtotals for Part A and B, or Part A and C. Suggested Decision Classes denoting the range of scores for the **Low**, **Moderate**, and **High** Survival Potential classes follow the Composite Rating Score. The Composite Rating Score is compared with the Suggested Decision Classes to determine the appropriate relative survival potential or class. In Appendix 2, we have provided a summary of the criteria with their respective rating ranges for each of the Decision Classes for each conifer species included in this rating procedure system.

The rating system enables the determination of relative tree survival up to one year after the fire for all conifer species included in the procedure. These ratings incorporate factors that take into account insects that may attack the trees within that period of time; hence, contributing to tree mortality along with first order fire effects. A set of rating factors has also been included to rate relative potential survival of large-diameter, mature or overmature ponderosa pine for more than one year, since much evidence is accruing

for delayed mortality of that stand component, especially between the second through fourth year following the fire (Scott 2002). In addition, the rating systems for ponderosa pine, Douglas-fir, and western white pine distinguish between tree sizes, since there is a size-related preference by some of the insect species that sometimes become influential mortality factors in fire-injured trees of these species, following fire.

Part A. Factors common to all species and size classes (except as noted):

(Instructions: Assign the appropriate rating value in parentheses to each factor below, then subtotal score)

FACTOR **RATING**

1. **Season of Fire** (Wagener 1961)
   a. Early-season Spring prescribed fire. (0)
   b. Late-season fire: Fire occurred on or after August 1st. (1)
   c. Early-season wildfire: Fire occurred before August 1st. (2)

2. **Pre-Fire Vigor, Growth Rate, and Site Quality** (Wagener 1961)
   a. Trees injured by fire growing relatively well, or on good to moderate sites. (0)
   b. Trees injured by fire exhibiting poor vigor or growth, or growing on poor quality sites. (1)

3. **Arrangement or Distribution of Down Woody Material** (Scott 2002)
   a. No large, down, woody debris within a distance of one-half the crown diameter beyond drip-line of fire-injured tree. (0)
   b. Large, down, woody debris in contact with fire-injured bole or within a distance of one-half the crown diameter beyond drip-line of tree. (1)

4. **Dwarf Mistletoe Occurrence** (Hawksworth and Wiens 1996)
   a. No dwarf mistletoe present in fire-injured trees. (0)
   b. Dwarf mistletoe present with DMR $\leq$ 3 in fire-injured tree. (1)
   c. Dwarf mistletoe present with DMR > 3 in fire-injured tree. (2)

5. **Root Disease Occurrence for True Firs and Douglas-fir Only** (Shaw and Kile 1991)
   a. Site or area containing fire-injured tree with no known root disease present. (0)
   b. Root disease known to be present on site or area containing fire-injured tree. (1)

6. **Bark Beetle Pressure—Infestations Last Year or Known Current Year** (Scott 1996)
   What is the relative distance from this stand to the nearest known infestation of a bark beetle species that could infest the host tree species being evaluated in this stand?
   a. > 2.0 miles (1)
   b. 0.25-2.0 miles (2)
   c. < 0.25 miles (3)

Subtotal Rating Score for Part A: _____

Continue to Part B or Part C as appropriate . . .

Part B. Factors for Determining Tree Survival up to 1 Year After Fire:

(Instructions: Assign the appropriate rating value in parentheses to each factor below, then subtotal score)

Ponderosa Pine *(Young and Immature Trees <180 years old – Barrett 1979)*

FACTOR **RATING**

7. **Crown Volume Scorch** (Powell 1997; Schmitt and Spiegel 2002)
   a. No visible scorching of crown present. (0)
   b. Crown volume scorched is < 40% of pre-fire live crown. (2)
   c. Crown volume scorched is 40-69% of pre-fire live crown. (4)
   d. Crown volume scorched is > 70% of pre-fire live crown. (6)

8. **Bole Scorch** (Schmitt and Spiegel 2002; Ryan 1988; Wagener 1960)
   a. No visible scorching of bole present. (0)
   b. < 30% circumference of bole scorched or blackened up to 1 ft. (1)
      Little or no (< one-quarter of circumference) cambial kill on bole or root crown area.
   c. 30-50% circumference of bole scorched or blackened from 2 to 8 ft. (2)
      > 75% cambium is alive at the root collar.
   d. > 50% circumference of bole charred to 8 ft. or more. (3)
      < 75% cambium is alive at the root collar.

9. **Total Scorch Height** (Based on Appendix 1, Tables 1-8)
   (Use nearest diameter below to diameter of tree being evaluated)
   a. For trees **5 in.** dbh :
      Total scorch height between 0-7 ft. (mean mortality probability 55.0%) (1)
      Total scorch height between 8-13 ft. (mean mortality probability 60.9%) (2)
      Total scorch height between 14-30 ft. (mean mortality probability 90.2%) (3)

   b. For trees **7 in.** dbh :
      Total scorch height between 0-17 ft. (mean mortality probability 41.0%) (1)
      Total scorch height between 18-27 ft. (mean mortality probability 56.3%) (2)
      Total scorch height between 28-50 ft. (mean mortality probability 92.9%) (3)

   c. For trees **9 in.** dbh :
      Total scorch height between 0-29 ft. (mean mortality probability 30.4%) (1)
      Total scorch height between 30-37 ft. (mean mortality probability 56.0%) (2)
      Total scorch height between 38-60 ft. (mean mortality probability 93.9%) (3)

   d. For trees **12 in.** dbh :
      Total scorch height between 0-37 ft. (mean mortality probability 19.7%) (1)
      Total scorch height between 38-49 ft. (mean mortality probability 54.4%) (2)
      Total scorch height between 50-76 ft. (mean mortality probability 89.9%) (3)

e. For trees 1**5 in.** dbh :
Total scorch height between 0-45 ft. (mean mortality probability 13.0%) (1)
Total scorch height between 46-57 ft. (mean mortality probability 49.4%) (2)
Total scorch height between 58-86 ft. (mean mortality probability 78.6%) (3)

f. For trees **18 in.** dbh :
Total scorch height between 0-55 ft. (mean mortality probability 9.5%) (1)
Total scorch height between 56-69 ft. (mean mortality probability 37.0%) (2)
Total scorch height between 70-100 ft. (mean mortality probability 88.1%) (3)

g. For trees **21 in.** dbh :
Total scorch height between 0-63 ft. (mean mortality probability 7.1%) (1)
Total scorch height between 64-79 ft. (mean mortality probability 54.1%) (2)
Total scorch height between 80-106 ft. (mean mortality probability 88.1%) (3)

h. For trees **26 in.** dbh :
Total scorch height between 0-73 ft. (mean mortality probability 4.1%) (1)
Total scorch height between 74-91 ft. (mean mortality probability 55.1%) (2)
Total scorch height between 92-116 ft. (mean mortality probability 85.2%) (3)

10. **Duff Consumption (Ryan and Noste 1985)**

a. For **Small Trees** Only (< 16 in. dbh): Leaf litter and/or duff charred or consumed, in part or entire; mineral soil may be exposed. (0)

b. For **Large Trees** Only (> 16 in. dbh): Leaf litter charred or consumed; upper duff charred, but not altered over entire depth; duff consumption usually < 4 in. (0)

c. For **Large Trees** Only (> 16 in. dbh): Leaf litter consumed; duff deeply charred or consumed, but underlying mineral soil is not visibly altered. (2)

d. For **Large Trees** Only (> 16 in. dbh): Litter and duff completely consumed, and top layer of mineral soil is visibly altered, often reddish. (4)

Subtotal Rating Score for Part B: _____

Composite Rating Score Part A+B: _____

Suggested Decision Classes:

(Refer to Appendix 2 For Rating Range Determinations)

Young and Immature Ponderosa Pine (Small Trees < 16 in. dbh)

High Probability of Tree Surviving = Composite Rating Score Ranging from **3-8**
Moderate Probability of Tree Surviving = Composite Rating Score Ranging from **10-15**
Low Probability of Tree Surviving = Composite Rating Score Ranging from **17-21**

Young and Immature Ponderosa Pine (Large Trees > 16 in. dbh)

High Probability of Tree Surviving = Composite Rating Score Ranging from **3-9**
Moderate Probability of Tree Surviving = Composite Rating Score Ranging from **13-18**
Low Probability of Tree Surviving = Composite Rating Score Ranging from **21-25**

Ponderosa Pine *(Mature and Overmature Trees >180 years old – Barrett 1979)*

FACTOR **RATING**

7. Crown Volume Scorch (Powell 1997; Ryan 1990)

a. No visible scorching of crown present. (0)
b. Crown volume scorched is < 50% of pre-fire live crown. (2)
c. Crown volume scorched is 50-80% of pre-fire live crown. (4)
d. Crown volume scorched is > 80% of pre-fire live crown. (6)

8. **Bole Scorch** (Ryan 1988; Wagener 1960; Schmitt and Spiegel 2002)

a. No visible scorching of bole or damage to cambium present. (0)
b. Bole scorch may or may not be present; some scorching at root collar. (1)
Dead cambium on bole or root crown area < one-quarter of circumference and not extending above stump height, except for narrow strip kill above.
c. 30-50% circumference of bole scorched or blackened from 2 to 8 ft. (2)
and > 75% cambium is alive at the root collar.
d. > 50% circumference of bole charred to 8 ft. or more; integrity of bark (3)
clearly altered or deeply burned over a portion of the circumference,
and < 75% cambium is alive at the root collar.

9. **Total Scorch Height** (Based on Appendix 1, Tables 9-10)
(Use nearest diameter below to diameter of tree being evaluated)

a. <u>For trees **32 in.** dbh :</u>
Total scorch height between 0-83 ft. (mean mortality probability 3.0%) (1)
Total scorch height between 84-109 ft. (mean mortality probability 53.4%) (2)
Total scorch height between 110-134 ft. (mean mortality probability 81.6%) (3)

b. <u>For trees **40 in.** dbh :</u>
Total scorch height between 0-103 ft. (mean mortality probability 5.1%) (1)
Total scorch height between 104-127 ft. (mean mortality probability 61.3%) (2)
Total scorch height between 128-144 ft. (mean mortality probability 79.5%) (3)

10. **Duff Consumption** (Ryan 1990; Ryan and Frandsen 1991; Ryan and Noste 1985)

a. Leaf litter charred or consumed; upper duff charred, but not altered (0)
over entire depth; duff consumption < 4 in.
b. Leaf litter consumed; duff deeply charred or consumed, but underlying (3)
mineral soil is not visibly altered; duff consumption 4-7 in.
c. Litter and duff completely consumed, and top layer of mineral soil (6)
visibly altered, often reddish; duff consumption exceeded 7 in.

Subtotal Rating Score for Part B: _____

Composite Rating Score Part A+B: _____

Suggested Decision Classes:

(Refer to Appendix 2 For Rating Range Determinations)

Mature and Overmature Ponderosa Pine

High Probability of Tree Surviving = Composite Rating Score Ranging from	**3-8**
Moderate Probability of Tree Surviving = Composite Rating Score Ranging from	**10-18**
Low Probability of Tree Surviving = Composite Rating Score Ranging from	**21-27**

Douglas-fir *(Young and Immature Trees <20 in. dbh)*

FACTOR **RATING**

7. **Crown Volume Scorch** (Reinhardt and Ryan 1989; Wagener 1961; Wyant and others 1986)
   a. No visible scorching (0)
   b. Crown volume scorched is <25% (20% mortality for 14" trees) (2)
   c. Crown volume scorched is 25-55% (20-50% mortality for 14" trees) (4)
   d. Crown volume scorched is 55-75% (50-80% mortality) (6)
   e. Crown volume scorched is >75% (>80% mortality) (8)

8. **Bole Char** (Schmitt and Spiegel 2002, Scott and others 1996)
   a. No visible char (0)
   b. <30% of bole circumference blackened (20% mortality) (1)
   c. 30-50% of bole circumference blackened and >75% live cambium around the base (40% mortality) (2)
   d. 50-75% of bole circumference blackened and >75% live cambium around the base (50% mortality) (3)
   e. >75% of bole circumference blackened and <75% live cambium around the base (>50% mortality) (4)

9. **Total Scorch Height** (Reinhardt and Ryan 1988; Ryan and Reinhardt 1988)
   (Use nearest diameter below to diameter of tree being evaluated)
   a. For trees **9 in.** dbh :
      Total scorch height between 0-30 ft. (mean mortality probability 30.0%) (1)
      Total scorch height between 31-42 ft. (mean mortality probability 59.2%) (2)
      Total scorch height between 43-60 ft. (mean mortality probability 97.0%) (3)

   b. For trees **12 in.** dbh :
      Total scorch height between 0-36 ft. (mean mortality probability 19.0%) (1)
      Total scorch height between 37-54 ft. (mean mortality probability 52.1%) (2)
      Total scorch height between 55-70 ft. (mean mortality probability 96.0%) (3)

   c. For trees **15 in.** dbh :
      Total scorch height between 0-44 ft. (mean mortality probability 12.0%) (1)
      Total scorch height between 45-64 ft. (mean mortality probability 41.1%) (2)
      Total scorch height between 65-84 ft. (mean mortality probability 92.8%) (3)

   d. For trees **18 in.** dbh :
      Total scorch height between 0-44 ft. (mean mortality probability 8.0%) (1)
      Total scorch height between 45-68 ft. (mean mortality probability 32.4%) (2)
      Total scorch height between 69-88 ft. (mean mortality probability 90.2%) (3)

10. **Duff Consumption** (Ryan and Noste 1985)
    a. Leaf litter charred or consumed; upper duff charred, but not altered (0)

over entire depth.

b. Leaf litter consumed; duff deeply charred or consumed, but underlying mineral soil is not visibly altered. (2)

c. Litter and duff completely consumed, and top layer of mineral soil visibly altered, often reddish. (4)

Subtotal Rating Score for Part B: _____

Composite Rating Score Part A+B: _____

Suggested Decision Classes:

(Refer to Appendix 2 For Rating Range Determinations)

Young and Immature Douglas-fir

High Probability of Tree Surviving = Composite Rating Score Ranging from **3-7**

Moderate Probability of Tree Surviving = Composite Rating Score Ranging from **8-16**

Low Probability of Tree Surviving = Composite Rating Score Ranging from **17-25**

Douglas-fir *(Mature and Overmature Trees >20 in. dbh)*

FACTOR **RATING**

7. **Crown Volume Scorch** (Reinhardt and Ryan 1989; Wagener 1961)
   a. No visible scorching (0)
   b. Crown volume scorched is <30% (10% mortality for 20" trees) (2)
   c. Crown volume scorched is 30-50% (20% mortality for 20" trees) (4)
   d. Crown volume scorched is 50-80% (20-80% mortality for 20" trees) (6)
   e. Crown volume scorched is >80% (>80% mortality for 20" trees) (8)

8. **Bole Char** (Peterson and Arbaugh 1989; Scott and others 1996; Furniss 1965)
   a. No visible charring of outer bark. (0)
   b. <30% of bole circumference charred up to 1.5 ft. (1)
   c. 30-50% of bole circumference charred up to 2-5 ft. (2)
      Char not affecting cambium; potential for some root damage (57-86% of trees may be attacked by DFB—Furniss 1965).
   d. >50% of bole circumference charred up to 5-8 ft. (3)
      Visible damage to phloem <25% of tree's circumference at base of tree near ground (90-92% of trees may be attacked by DFB—Furniss 1965).
   e. >50% of bole circumference charred up to >8 ft. (4)
      Visible damage to phloem >25% of tree's circumference at base of tree near ground (43-82% of trees may be attacked by DFB—Furniss 1965).

9. **Total Scorch Height** (Bevins 1980)
   (Use nearest diameter below to diameter of tree being evaluated)
   a. For trees 21 **in.** dbh :
      Total scorch height between 0-57 ft. (survival probability range 70-100%) (1)
      Total scorch height between 58-84 ft. (survival probability range 30-69%) (2)
      Total scorch height >84 ft. (survival probability range <30%) (3)

   b. For trees **26 in.** dbh :
      Total scorch height between 0-75 ft. (survival probability range 70-100%) (1)
      Total scorch height between 76-98 ft. (survival probability range 30-69%) (2)
      Total scorch height >98 ft. (survival probability range <30%) (3)

   c. For trees **30 in.** dbh :
      Total scorch height between 0-83 ft. (survival probability range 70-100%) (1)
      Total scorch height between 84-108 ft. (survival probability range 30-69%) (2)
      Total scorch height >108 ft. (survival probability range <30%) (3)

   d. For trees **32 in.** dbh :
      Total scorch height between 0-87 ft. (survival probability range 70-100%) (1)

Total scorch height between 88-112 ft. (survival probability range 30-69%) (2)
Total scorch height >112 ft. (survival probability range <30%) (3)

10. **Duff Consumption** (Ryan 1990; Ryan and Frandsen 1991; Ryan and Noste 1985)
    a. Leaf litter charred or consumed; upper duff charred, but not altered over entire depth. (0)
    b. Leaf litter consumed; duff deeply charred or consumed, but underlying mineral soil is not visibly altered. (3)
    c. Litter and duff completely consumed, and top layer of mineral soil visibly altered, often reddish. (4)

Subtotal Rating Score for Part B: _____

Composite Rating Score Part A+B: _____

Suggested Decision Classes:

(Refer to Appendix 2 For Rating Range Determinations)

Mature and Overmature Douglas-fir

High Probability of Tree Surviving = Composite Rating Score Ranging from **3-10**
Moderate Probability of Tree Surviving = Composite Rating Score Ranging from **11-17**
Low Probability of Tree Surviving = Composite Rating Score Ranging from **19-31**

Engelmann Spruce *(All Size Classes except as noted)*

FACTOR **RATING**

7. **Crown Volume Scorch** (Ryan and Reinhardt 1988; Smith & Fischer 1997)
   a. No visible scorching (0)
   b. Crown volume scorched is ≤25% (80.0% mortality for 9" trees) (3)
   c. Crown volume scorched is 26-55% (84.4% mortality for 9" trees) (6)
   d. Crown volume scorched is 55-75% (92.5% mortality for 9" trees) (9)
   e. Crown volume scorched is >75% (>93% mortality for 9" trees) (12)

8. **Bole/Root Char at Ground Level** (Weatherby and others 2001)
   a. No visible char (0)
   b. <40% of bole circumference blackened (3)
   c. 40-70% of bole circumference blackened (mortality >50% at 50% char) (6)
   d. >70% of bole circumference blackened (9)

9. **Total Scorch Height** (Reinhardt and Ryan 1988; Ryan and Reinhardt 1988)
   (Use nearest diameter below to diameter of tree being evaluated)
   a. No bole scorch evident. (0)
   b. For trees **9 in.** dbh :
      Total scorch height between 0-25 ft. (mean mortality probability 80.0%) (1)
      Total scorch height between 26-40 ft. (mean mortality probability 88.0%) (2)
      Total scorch height between 41-60 ft. (mean mortality probability 99.5%) (3)

   c. For trees **15 in.** dbh :
      Total scorch height between 0-45 ft. (mean mortality probability 80.0%) (1)
      Total scorch height between 46-65 ft. (mean mortality probability 87.5%) (2)
      Total scorch height between 65-90 ft. (mean mortality probability 98.5%) (3)

   d. For trees **21 in.** dbh :
      Total scorch height between 0-65 ft. (mean mortality probability 80.0%) (1)
      Total scorch height between 66-85 ft. (mean mortality probability 87.7%) (2)
      Total scorch height between 86-110 ft. (mean mortality probability 97.5%) (3)

10. **Duff Consumption** (Ryan 1990; Ryan and Frandsen 1991; Ryan and Noste 1985)
    a. Leaf litter charred or consumed; upper duff charred, but not altered over entire depth. (0)
    b. Leaf litter consumed; duff deeply charred or consumed, but underlying mineral soil is not visibly altered. (1)
    c. Litter and duff completely consumed, and top layer of mineral soil visibly altered, often reddish. (2)

Subtotal Rating Score for Part B: _____

Composite Rating Score Part A+B: _____

Suggested Decision Classes:

(Refer to Appendix 2 For Rating Range Determinations)

All Size Classes of Engelmann Spruce

High Probability of Tree Surviving = Composite Rating Score Ranging from	**2-6**
Moderate Probability of Tree Surviving = Composite Rating Score Ranging from	**9-14**
Low Probability of Tree Surviving = Composite Rating Score Ranging from	**19-33**

Lodgepole Pine *(All Size Classes except as noted)*

FACTOR **RATING**

7. **Crown Volume Scorch** (Ryan and Reinhardt 1989; Weatherby and others 2001)
   a. No visible scorching (0)
   b. Crown volume scorched is ≤20% (63% mortality all trees ≤9") (1)
   c. Crown volume scorched is 20-50% (80.0% mortality for 9" trees) (2)
   d. Crown volume scorched is >50% (>80% mortality for 9" trees) (3)

8. **Bole/Root Char** (Weatherby and others 2001)
   a. No visible char (0)
   b. <30% of bole circumference blackened (20% mortality) (3)
   c. 30-60% of bole circumference blackened (40% mortality) (6)
   d. >60% of bole circumference blackened (≥50% mortality) (9)

9. **Total Scorch Height** (Reinhardt and Ryan 1988; Ryan and Reinhardt 1988)
   (Use nearest diameter below to diameter of tree being evaluated)
   a. For trees **9 in.** dbh :
      Total scorch height between 0-28 ft. (mean mortality probability 63.0%) (1)
      Total scorch height between 29-38 ft. (mean mortality probability 72.2%) (2)
      Total scorch height between 39-58 ft. (mean mortality probability 98.4%) (3)

   b. For trees **15 in.** dbh :
      Total scorch height between 0-40 ft. (mean mortality probability 44.0%) (1)
      Total scorch height between 41-56 ft. (mean mortality probability 65.9%) (2)
      Total scorch height between 57-80 ft. (mean mortality probability 97.5%) (3)

   c. For trees **21 in.** dbh :
      Total scorch height between 0-46 ft. (mean mortality probability 30.0%) (1)
      Total scorch height between 47-64 ft. (mean mortality probability 54.7%) (2)
      Total scorch height between 65-90 ft. (mean mortality probability 96.0%) (3)

10. **Duff Consumption** (Ryan 1990; Ryan and Frandsen 1991; Ryan and Noste 1985)
   a. Leaf litter charred or consumed; upper duff charred, but not altered over entire depth. (1)
   b. Leaf litter consumed; duff deeply charred or consumed, but underlying mineral soil is not visibly altered. (2)
   c. Litter and duff completely consumed, and top layer of mineral soil visibly altered, often reddish. (4)

Subtotal Rating Score for Part B: _____

Composite Rating Score Part A+B: _____

Suggested Decision Classes:

(Refer to Appendix 2 For Rating Range Determinations)

All Size Classes of Lodgepole Pine

High Probability of Tree Surviving = Composite Rating Score Ranging from	**4-8**
Moderate Probability of Tree Surviving = Composite Rating Score Ranging from	**9-18**
Low Probability of Tree Surviving = Composite Rating Score Ranging from	**21-28**

Western Larch *(All Size Classes except as noted)*

FACTOR **RATING**

7. **Crown Volume Scorch** (Peterson 1983; Scott and others 1996)
   a. No visible scorching (0)
   b. Crown volume scorched is ≤10% (<25% mortality for 6" trees) (<10% mortality for 16" trees) (1)
   c. Crown volume scorched is 10-25% (25-35% mortality for 6" trees) (10-16% mortality for 16" trees) (2)
   d. Crown volume scorched is 26-50% (36-53% mortality for 6" trees) (17-30% mortality for 16" trees) (3)
   e. Crown volume scorched is 51-75% (54-70% mortality for 6" trees) (31-50% mortality for 16" trees) (4)

8. **Bole Char** (Undetermined)

9. **Total Scorch Height** (Reinhardt and Ryan 1988; Ryan and Reinhardt 1988)
   (Use nearest diameter below to diameter of tree being evaluated)
   a. For trees **5 in.** dbh :
      Total scorch height between 0-21 ft. (mean mortality probability 55.0%) (1)
      Total scorch height between 22-27 ft. (mean mortality probability 71.0%) (2)
      Total scorch height between 28-40 ft. (mean mortality probability 97.7%) (3)

   b. For trees **9 in.** dbh :
      Total scorch height between 0-32 ft. (mean mortality probability 30.0%) (1)
      Total scorch height between 33-46 ft. (mean mortality probability 61.0%) (2)
      Total scorch height between 47-62 ft. (mean mortality probability 97.2%) (3)

   c. For trees **15 in.** dbh :
      Total scorch height between 0-48 ft. (mean mortality probability 12.0%) (1)
      Total scorch height between 49-74 ft. (mean mortality probability 47.0%) (2)
      Total scorch height between 75-92 ft. (mean mortality probability 94.4%) (3)

   d. For trees **21 in.** dbh :
      Total scorch height between 0-62 ft. (mean mortality probability 6.0%) (1)
      Total scorch height between 63-96 ft. (mean mortality probability 34.5%) (2)
      Total scorch height between 97-118 ft. (mean mortality probability 89.4%) (3)

10. **Duff Consumption** (Ryan 1990; Ryan and Frandsen 1991; Ryan and Noste 1985)
   a. Leaf litter charred or consumed; upper duff charred, but not altered over entire depth. (0)
   b. Leaf litter consumed; duff deeply charred or consumed, but underlying mineral soil is not visibly altered. (2)
   c. Litter and duff completely consumed, and top layer of mineral soil visibly altered, often reddish. (4)

Subtotal Rating Score for Part B: _____

Composite Rating Score Part A+B: _____

Suggested Decision Classes:

(Refer to Appendix 2 For Rating Range Determinations)

All Size Classes of Western Larch

High Probability of Tree Surviving = Composite Rating Score Ranging from	**3-6**
Moderate Probability of Tree Surviving = Composite Rating Score Ranging from	**7-13**
Low Probability of Tree Surviving = Composite Rating Score Ranging from	**14-17**

Grand Fir and White Fir *(All Size Classes except as noted)*

FACTOR **RATING**

7. **Crown Volume Scorch** (Reinhardt and Ryan 1988; Ryan and Reinhardt 1988)
   a. No visible scorching (0)
   b. Crown volume scorched is ≤10% (<46% mortality for 9" trees) (1)
   c. Crown volume scorched is 10-25% (47-52% mortality for 9" trees) (2)
   d. Crown volume scorched is 26-50% (53-78% mortality for 9" trees) (3)
   e. Crown volume scorched is 51-75% (79-99% mortality for 9" trees) (4)

8. **Bole Char at Ground Level** (Scott and others 1996, with modification)
   a. No charring present on bole. (0)
   b. <10% of basal circumference of bole charred (1)
   c. 10-30% of basal circumference of bole charred (3)
   d. 30-40% of basal circumference of bole charred (6)
   e. >40% of bole circumference charred (9)

9. **Total Scorch Height** (Reinhardt and Ryan 1988; Ryan and Reinhardt 1988)
   (Use nearest diameter below to diameter of tree being evaluated)
   a. For trees **7 in.** dbh :
      Total scorch height between 0-24 ft. (mean mortality probability 55.0%) (1)
      Total scorch height between 25-32 ft. (mean mortality probability 67.5%) (2)
      Total scorch height between 33-50 ft. (mean mortality probability 97.2%) (3)

   b. For trees **9 in.** dbh :
      Total scorch height between 0-32 ft. (mean mortality probability 45.0%) (1)
      Total scorch height between 33-44 ft. (mean mortality probability 65.5%) (2)
      Total scorch height between 45-64 ft. (mean mortality probability 97.2%) (3)

   c. For trees **15 in.** dbh :
      Total scorch height between 0-46 ft. (mean mortality probability 23.0%) (1)
      Total scorch height between 47-70 ft. (mean mortality probability 53.3%) (2)
      Total scorch height between 71-92 ft. (mean mortality probability 96.3%) (3)

   d. For trees **21 in.** dbh :
      Total scorch height between 0-54 ft. (mean mortality probability 12%) (1)
      Total scorch height between 55-88 ft. (mean mortality probability 45.9%) (2)
      Total scorch height between 89-108 ft. (mean mortality probability 95.0%) (3)

10. **Duff Consumption** (Ryan 1990; Ryan and Frandsen 1991; Ryan and Noste 1985)
    a. No leaf litter or duff scorched or consumed (0)
    b. Leaf litter charred or consumed; upper duff charred, but not altered over entire depth. (1)
    c. Leaf litter consumed; duff deeply charred or consumed, but underlying mineral soil is not visibly altered. (2)

d. Litter and duff completely consumed, and top layer of mineral soil visibly altered, often reddish. (6)

Subtotal Rating Score for Part B: _____

Composite Rating Score Part A+B: _____

Suggested Decision Classes:

(Refer to Appendix 2 For Rating Range Determinations)

All Size Classes of Grand Fir and White Fir

High Probability of Tree Surviving = Composite Rating Score Ranging from	**3-4**
Moderate Probability of Tree Surviving = Composite Rating Score Ranging from	**5-10**
Low Probability of Tree Surviving = Composite Rating Score Ranging from	**11-30**

Subalpine Fir *(All Size Classes except as noted)*

FACTOR **RATING**

7. **Crown Volume Scorch** (Peterson 1983)
   - a. No visible scorching (0)
   - b. Crown volume scorched is ≤10% (<38% mortality for 6" trees) (<30% mortality for 16" trees) (1)
   - c. Crown volume scorched is 10-25% (39-48% mortality for 6" trees) (31-44% mortality for 16" trees) (2)
   - d. Crown volume scorched is 26-50% (49-69% mortality for 6" trees) (45-63% mortality for 16" trees) (3)
   - e. Crown volume scorched is 51-75% (69-85% mortality for 6" trees) (64-78% mortality for 16" trees) (4)

8. **Bole Char at Ground Level** (Scott and others 1996, with modification)
   - a. No charring present on bole. (0)
   - b. <10% of basal circumference of bole charred (1)
   - c. 10-30% of basal circumference of bole charred (3)
   - d. 30-40% of basal circumference of bole charred (6)
   - e. >40% of bole circumference charred (9)

9. **Total Scorch Height** (Reinhardt and Ryan 1988; Ryan and Reinhardt 1988)
   (Use nearest diameter below to diameter of tree being evaluated)
   - a. For trees **7 in.** dbh :
     - Total scorch height between 0-22 ft. (mean mortality probability 59.0%) (1)
     - Total scorch height between 23-28 ft. (mean mortality probability 72.7%) (2)
     - Total scorch height between 29-44 ft. (mean mortality probability 97.7%) (3)
   - b. For trees **9 in.** dbh :
     - Total scorch height between 0-30 ft. (mean mortality probability 55.0%) (1)
     - Total scorch height between 31-40 ft. (mean mortality probability 71.8%) (2)
     - Total scorch height between 41-58 ft. (mean mortality probability 97.9%) (3)
   - c. For trees **15 in.** dbh :
     - Total scorch height between 0-40 ft. (mean mortality probability 28.0%) (1)
     - Total scorch height between 41-58 ft. (mean mortality probability 57.8%) (2)
     - Total scorch height between 59-78 ft. (mean mortality probability 96.9%) (3)
   - d. For trees **21 in.** dbh :
     - Total scorch height between 0-44 ft. (mean mortality probability 15%) (1)
     - Total scorch height between 45-70 ft. (mean mortality probability 45.1%) (2)
     - Total scorch height between 71-90 ft. (mean mortality probability 94.9%) (3)

10. **Duff Consumption** (Ryan 1990; Ryan and Frandsen 1991; Ryan and Noste 1985)
    - a. No leaf litter or duff scorched or consumed (0)
    - b. Leaf litter charred or consumed; upper duff charred, but not altered (1)

over entire depth.

c. Leaf litter consumed; duff deeply charred or consumed, but underlying mineral soil is not visibly altered. (2)

d. Litter and duff completely consumed, and top layer of mineral soil visibly altered, often reddish. (6)

Subtotal Rating Score for Part B: _____

Composite Rating Score Part A+B: _____

Suggested Decision Classes:

(Refer to Appendix 2 For Rating Range Determinations)

All Size Classes of Subalpine Fir

High Probability of Tree Surviving = Composite Rating Score Ranging from **3-4**

Moderate Probability of Tree Surviving = Composite Rating Score Ranging from **5-10**

Low Probability of Tree Surviving = Composite Rating Score Ranging from **11-30**

Western White Pine *(Young and Immature Trees <20 in. dbh)*

FACTOR **RATING**

7. **Crown Volume Scorch** (Reinhardt and Ryan 1988; Ryan and Reinhardt 1988)
   a. No visible scorching (0)
   b. Crown volume scorched is ≤10% (≤57% mortality for 9" trees) (2)
      (≤35% mortality for 15" trees)
      (≤27% mortality for 18" trees)
   c. Crown volume scorched is 10-25% (58-63% mortality for 9" trees) (4)
      (36-49% mortality for 15" trees)
      (28-33% mortality for 18" trees)
   d. Crown volume scorched is 26-50% (64-85% mortality for 9" trees) (6)
      (50-68% mortality for 15" trees)
      (34-60% mortality for 18" trees)
   e. Crown volume scorched is 51-75% (86-96% mortality for 9" trees) (8)
      (69-91% mortality for 15" trees)
      (61-87% mortality for 18" trees)

8. **Bole Char** (Undetermined)

9. **Total Scorch Height** (Reinhardt and Ryan 1988; Ryan and Reinhardt 1988)
   (Use nearest diameter below to diameter of tree being evaluated)
   a. For trees **9 in.** dbh :
      Total scorch height between 0-32 ft. (mean mortality probability 56.0%) (1)
      Total scorch height between 33-42 ft. (mean mortality probability 70.8%) (2)
      Total scorch height between 43-64 ft. (mean mortality probability 97.6%) (3)

   b. For trees **12 in.** dbh :
      Total scorch height between 0-38 ft. (mean mortality probability 44.0%) (1)
      Total scorch height between 39-54 ft. (mean mortality probability 63.7%) (2)
      Total scorch height between 55-78 ft. (mean mortality probability 97.3%) (3)

   c. For trees **15 in.** dbh :
      Total scorch height between 0-44 ft. (mean mortality probability 35.0%) (1)
      Total scorch height between 45-62 ft. (mean mortality probability 62.3%) (2)
      Total scorch height between 63-86 ft. (mean mortality probability 97.0%) (3)

   d. For trees **18 in.** dbh :
      Total scorch height between 0-56 ft. (mean mortality probability 27%) (1)
      Total scorch height between 57-82 ft. (mean mortality probability 55.8%) (2)
      Total scorch height between 83-110 ft. (mean mortality probability 96.6%) (3)

10. **Duff Consumption** (Ryan 1990; Ryan and Frandsen 1991; Ryan and Noste 1985)
    a. Leaf litter charred or consumed; upper duff charred, but not altered over entire depth. (0)

b. Leaf litter consumed; duff deeply charred or consumed, but underlying mineral soil is not visibly altered. (1)

c. Litter and duff completely consumed, and top layer of mineral soil visibly altered, often reddish. (2)

Subtotal Rating Score for Part B: _____

Composite Rating Score Part A+B: _____

Suggested Decision Classes:

(Refer to Appendix 2 For Rating Range Determinations)

Young and Immature Western White Pine

High Probability of Tree Surviving = Composite Rating Score Ranging from **2-4**
Moderate Probability of Tree Surviving = Composite Rating Score Ranging from **6-10**
Low Probability of Tree Surviving = Composite Rating Score Ranging from **12-20**

Western White Pine *(Mature and Overmature Trees >20 in. dbh)*

FACTOR **RATING**

7. **Crown Volume Scorch** (Reinhardt and Ryan 1988; Ryan and Reinhardt 1988)
   a. No visible scorching (0)
   b. Crown volume scorched is ≤10% (≤21% mortality for 21" trees) (2)
      (≤14% mortality for 26" trees)
      (≤9% mortality for 32" trees)
   c. Crown volume scorched is 10-25% (22-26% mortality for 21" trees) (4)
      (15-18% mortality for 26" trees)
      (10-11% mortality for 32" trees)
   d. Crown volume scorched is 26-50% (27-52% mortality for 21" trees) (6)
      (19-38% mortality for 26" trees)
      (12-28% mortality for 32" trees)
   e. Crown volume scorched is 51-75% (53-84% mortality for 21" trees) (8)
      (39-76% mortality for 26" trees)
      (29-67% mortality for 32" trees)

8. **Bole Char** (Undetermined)

9. **Total Scorch Height** (Reinhardt and Ryan 1988; Ryan and Reinhardt 1988)
   (Use nearest diameter below to diameter of tree being evaluated)
   a. For trees 21 **in.** dbh :
      Total scorch height between 0-60 ft. (mean mortality probability 21%) (1)
      Total scorch height between 61-90 ft. (mean mortality probability 54.2%) (2)
      Total scorch height between 91-116 ft. (mean mortality probability 96.2%) (3)

   b. For trees **26 in.** dbh :
      Total scorch height between 0-66 ft. (mean mortality probability 14%) (1)
      Total scorch height between 67-104 ft. (mean mortality probability 49.6%) (2)
      Total scorch height between 105-128 ft. (mean mortality probability 95.4%) (3)

   c. For trees **32 in.** dbh :
      Total scorch height between 0-74 ft. (mean mortality probability 9%) (1)
      Total scorch height between 75-122 ft. (mean mortality probability 45.4%) (2)
      Total scorch height between 123-144 ft. (mean mortality probability 93.7%) (3)

   d. For trees **40 in.** dbh :
      Total scorch height between 0-84 ft. (mean mortality probability 6%) (1)
      Total scorch height between 85-140 ft. (mean mortality probability 46.1%) (2)
      Total scorch height between 141-156 ft. (mean mortality probability 91.7%) (3)

10. **Duff Consumption** (Ryan 1990; Ryan and Frandsen 1991; Ryan and Noste 1985)
    a. Leaf litter charred or consumed; upper duff charred, but not altered (0)

over entire depth.

b. Leaf litter consumed; duff deeply charred or consumed, but underlying mineral soil is not visibly altered. (1)

c. Litter and duff completely consumed, and top layer of mineral soil visibly altered, often reddish. (2)

Subtotal Rating Score for Part B: _____

Composite Rating Score Part A+B: _____

Suggested Decision Classes:

(Refer to Appendix 2 For Rating Range Determinations)

Mature and Overmature Western White Pine

High Probability of Tree Surviving = Composite Rating Score Ranging from **3-8**

Moderate Probability of Tree Surviving = Composite Rating Score Ranging from **9-14**

Low Probability of Tree Surviving = Composite Rating Score Ranging from **16-20**

Part C. Factors for Determining Tree Survival Beyond 1 Year After Fire:

(Instructions: Assign the appropriate rating value in parentheses to each factor below, then subtotal score)

Ponderosa Pine *(Mature and Overmature Trees >180 years old – Barrett 1979)*

FACTOR **RATING**

7. **Crown Volume Scorch** (Miller and Keen 1960; Scott et al. 1996; Salman 1934)
   a. No visible scorching of crown present. (0)
   b. Crown volume scorched is < 25% of pre-fire live crown. (1)
   c. Crown volume scorched is 25-50% of pre-fire live crown. (2)
   d. Crown volume scorched is > 50% of pre-fire live crown. (3)

8. **Bole Scorch** (Ryan 1988; Wagener 1960; Scott et al. 1996)
   a. No visible scorching of bole or damage to cambium present. (0)
   b. Bole scorch, when present, is ≤ 20 %; some scorching at root collar. (1)
      Dead cambium on bole or root crown area < one-quarter of circumference, and not extending above stump height except for narrow strip kill above.
   c. 30-50% circumference of bole scorched or blackened up to 40% of total tree height; > 75% cambium is alive at the root collar. (2)
   d. > 50% circumference of bole charred to > 40% of tree height; integrity of portion of the bark clearly altered or deeply burned over a portion of the tree's circumference; < 75% cambium is alive at the root collar. (3)

9. **Total Scorch Height** (Based on Appendix 1, Tables 9-10)
   (Use nearest diameter below to diameter of tree being evaluated)
   a. For trees **32 in.** dbh :
      Total scorch height between 0-83 ft. (mean mortality probability 3.0%) (1)
      Total scorch height between 84-109 ft. (mean mortality probability 53.4%) (2)
      Total scorch height between 110-134 ft. (mean mortality probability 81.6%) (3)

   b. For trees **40 in.** dbh :
      Total scorch height between 0-103 ft. (mean mortality probability 5.1%) (1)
      Total scorch height between 104-127 ft. (mean mortality probability 61.3%) (2)
      Total scorch height between 128-144 ft. (mean mortality probability 79.5%) (3)

10. **Duff Consumption** (Ryan 1990; Ryan and Frandsen 1991; Ryan and Noste 1985)
    a. Leaf litter charred or consumed; upper duff charred, but not altered over entire depth; duff consumption < 4 in. (0)
    b. Leaf litter consumed; duff deeply charred or consumed, but underlying mineral soil is not visibly altered; duff consumption 4-7 in. (3)
    c. Litter and duff completely consumed, and top layer of mineral soil (6)

visibly altered, often reddish; duff consumption exceeded 7 in.

Subtotal Rating Score for Part C: _____

Composite Rating Score Part A+C: _____

Suggested Decision Classes:

(Refer to Appendix 2 For Rating Range Determinations)

Mature and Overmature Ponderosa Pine Delayed Mortality

High Probability of Tree Surviving = Composite Rating Score Ranging from	**3-6**
Moderate Probability of Tree Surviving = Composite Rating Score Ranging from	**7-12**
Low Probability of Tree Surviving = Composite Rating Score Ranging from	**15-24**

Description of Rating System

Ryan (1990), Scott and others (1996), and Wagener (1961) previously reviewed many of the factors most affecting survival of fire-injured conifer tree species. The detailed discussion of those factors will not be repeated again here; however, we will highlight certain points for clarification of the rating factors. A detailed discussion of dwarf mistletoe and root disease occurrence has been included because these factors have not been previously used to help characterize survival of fire-injured trees. By including them, we elevate their importance as factors in the post-fire survival of conifers in the Blue and Wallowa Mountains.

Each of the factors comprising our rating system is keyed to specific references identifying or describing the relative importance of the factor to tree survival, or providing the criteria or probability equations for that factor which we incorporated into our rating system. The rating values assigned to each factor have been deliberately kept simple to facilitate ease in field scoring and computation of subtotal and composite scores. The Decision Class Rating Score ranges were developed based on a synthesis of several data sources including observations from past and current wildfire and prescribed fire monitoring (e.g., Scott and others 1996; Scott 2002), tree mortality probability model outputs (e.g., Andrews and Bevins 1999; Powell 1997; Reinhardt and Ryan 1989; Ryan and Reinhardt 1988), and graphical representations of results from actual prescribed fire or wildfire studies correlating degrees of fire injury with tree mortality or survival (e.g., Bevins 1980; Peterson 1983).

Organization

The rating system has been organized into three parts. **Part A** lists factors common to all species and sizes of trees. **Part B** and **C** contain fire injury factors specific to the given tree. Summing **Part A** with either **Part B** or **C** will give a composite score. This score can then be compared to the suggested ranges for a resulting **High**, **Moderate**, or **Low** probability of survival for a given tree.

The first part, **Part A**, contains the factors that may affect the overall vigor of trees involved in the fire by virtue of tree growth rates and the quality of site on which they are growing, or due to predisposition by weakening agents such as dwarf mistletoe or root diseases. The time of year in which the fire occurred is also considered in this part. Tree tissues are more vulnerable to injury by fire during active growth than they are when growth has slowed in the fall (Wagener 1961). Proximity of the fire to active insect infestations is also considered in this part. Insect populations close to a fire can sometimes cause many losses to trees that survived the fire, for several years after the fire. This is easily demonstrated by the dramatic population increases witnessed on the Summit Fire (Malheur NF) of 1997, and the Tower Fire (Umatilla NF) of 1997, a few years following those fires.

Parts B and C contain the specific fire injury factors that are most important in causing injury or death to living tissues of the tree, including injury to needles and buds, bole cambium, and roots and root cambium. Not all injuries of living tissues on trees are easily observed. For example, root injuries are typically hidden from view, and assessing damage is difficult without chopping into roots or excavating them for examination. We have attempted to include factors in the rating system that can easily be observed or obtained through direct measurement. These include measurements or estimates of crown volume scorch, bole scorch, total scorch height, and duff consumption (see Ryan and Noste 1983 for a discussion of vegetation response related to fire severity as determined by flame length class and ground char class). Because the degree of burning of duff and larger surface fuels determines the depth of lethal heat penetration into the soil (Ryan and Noste 1983), duff consumption, as used in this rating system, serves as a surrogate indicator for root injury. The quantity consumed, and characteristics of duff and exposed mineral soil observed can be related in a general way to degrees of root injury of various conifer species in the Blue and Wallowa Mountains.

Dwarf Mistletoes

Dwarf mistletoes (*Arceuthobium* spp.) occur throughout northeastern Oregon. Four species are present: *A. campylopodum* on ponderosa pine, *A. americanum* on lodgepole pine, *A laricis* on western larch and occasionally on lodgepole pine, and *A. douglasii* on Douglas-fir. Dwarf mistletoes are found throughout the host distribution of Douglas-fir and western larch in the Blue Mountains, varying substantially in occurrence and severity of infestation at stand levels. Conversely, occurrence of dwarf mistletoes of ponderosa pine and lodgepole pine varies substantially throughout the area host type. For example, *A. campylopodum* does not occur in the ponderosa pine types in the northern part of the Umatilla and Wallowa-Whitman National Forests, but is common in the southern Blue Mountains, especially on the Baker and Unity Districts of the Wallowa-Whitman and many portions of the Malheur National Forest. Substantial portions of the lodgepole pine type throughout the Blue Mountains are also uninfected.

Wildfires are the single most significant ecological factor in governing the distribution and abundance of dwarf mistletoes (Alexander and Hawksworth 1975, Wicker and Leaphart 1974). In most cases occurrence of dwarf mistletoes is reduced following stand replacement fires as hosts are killed and reinfection is much slower than re-establishment of host trees. Lighter burns can partially sanitize infected stands since infected trees, especially those that are severely infected, will be more likely to be killed as a result of ground fires being carried into the crown by low-hanging flammable brooms. This is especially true in Douglas-fir, but occurs also in ponderosa pine and lodgepole pine. In some cases fires can result in increased mistletoe infection. This is probably most common where infected seral species survive and fire-susceptible shade-tolerant regeneration under those residuals was killed. The most

common example of this is where larch and lodgepole pine regenerate under mistletoe-infected larch survivors replacing the true firs and Douglas-fir that had formed the understory.

Most stand types that have host conifers with mistletoe infections have not been visited by ground fire since the late 1800's when active fire suppression began. These stands often will have relatively high fuel loading and are therefore more susceptible to conflagrations than similar uninfected stands. Characteristic low-hanging brooms develop and persist, as they do not effectively self-prune. Often dead brooms are scattered around the bases of infected individuals where they have broken from the bole. Snags, the result of mistletoe-caused mortality and severely infected and stunted understory can also contribute to increased fire susceptibility. Carefully controlled fire can be used to clean up some of these fuels as well as to reduce average stand mistletoe levels by preferentially removing most severely infected trees (Koonce and Roth 1980). Studies in Colorado lodgepole pine communities have shown that more frequent fire intervals correspond to lower levels of dwarf mistletoe (Zimmerman and others 1990).

Following wildfires, dwarf mistletoe infected trees that survive can act as infection sources where susceptible species are planted or regenerate within trajectory spread distance. This distance will vary due to a number of factors, but can extend up to 100 feet horizontal distance from infected overstory although seed dispersal from these trees exponentially decreases over that distance.

Dwarf mistletoe-infected trees that initially survive wildfires are less likely to remain alive than similar uninfected trees. Tree vigor is impacted proportional to degree of dwarf mistletoe infection. Cumulative impacts on tree vigor by fire injury and that resulting from mistletoe infection should be considered when evaluating post-burn survivor potential. Harrington and Hawksworth (1990), investigating ponderosa pine in Arizona, found that with crown scorch between 40 and 90 percent, healthy trees were more than twice as likely to survive as severely infected trees during the first year after a fire. It is likely that delayed mortality in subsequent years will also be higher in mistletoe-infected trees than in healthy trees. Ponderosa pine seems most likely to be affected by delayed mortality (trees succumbing later than 1 year following the fire), and insects, primarily bark beetles and woodborers, are associated with tree death. Several studies indicate dwarf mistletoe infection renders ponderosa pine increasingly susceptible to bark beetles (Miller and Keen 1960, Owen 1985, Johnson and others 1976, McCambridge and others 1982) and wood borers (Swain and others 1974, Wood and others 1979). Fire damaged mistletoe-infected trees, especially ponderosa pine and Douglas-fir, are *probably* more likely to be subject to delayed insect attack from cumulative stresses of fire and mistletoe infection.

It is probable that dwarf mistletoe-infected larch, firs, and pines, have an increased likelihood of being killed from fire due to increased fuels and fire susceptibility. Dwarf mistletoe infection on fire-damaged trees should be easily identified in the field by branch brooming, spindle-shaped swellings, and aerial shoots of mistletoe observable on trees and on the ground under subject trees. These trees should be considered at higher risk to mortality than similar mistletoe-free trees in project documentation and salvage marking guides.

Root Diseases

A number of conifer root diseases are common in the Blue Mountains. Included are laminated root rot, caused by *Phellinus weirii*, Armillaria root disease, caused by *Armillaria ostoyae*, blackstain root disease, caused by *Leptographium wageneri*, and annosus root disease, caused by *Heterobasidion annosum*. These

root diseases often occur in centers that vary in size but are often many acres, although *H. annosum* centers seldom are more than half an acre in size. Root disease centers are usually characterized as having exceptionally high fuels due to on-going mortality. Even residual root disease-resistant and –tolerant cohorts are at risk during fires due to the adjacent heavy fuels.

Most applicable information available concerning fire and root disease describes the effects on conifer species composition and stand structure under current and historical fire regimes and the changes that have occurred over the last 120 or so years as a result of fire suppression (Byler and others 1990, Hagle and Goheen 1988). Historic frequent periodic fires in dry mixed conifer types were generally underburns and tended to remove the younger shade-tolerant species that had become established in the interim since the last fire. Historical fires in wet grand fir-dominated communities were infrequent stand replacement fires that likely regenerated to a substantial component of larch and lodgepole pine; that succeeded to shade tolerant species over time. Root disease is believed to have become established in affected sites but varied in prominence and activity proportional to the advancement of plant succession.

Many mixed conifer stands in the Blue Mountains have had several partial removal harvests, primarily for selection of the most valuable seral pines and larch as well as Douglas-fir. Fire has not occurred for a century or more. These stands now are typified by a substantial true fir component much greater than existed in recent historical times. Wildfire occurring now will usually kill a substantial proportion of stand composition, especially fire-susceptible true firs. If root disease, especially Armillaria, is present, stumps of fire-killed susceptible species, such as grand fir, represent a substantial inoculum base that *could* quickly become colonized, and *could* result in higher root disease activity subsequently on the site (Kile 1980). However, this scenario has not been documented in eastern Oregon.

Stands with active root disease activity usually support high endemic levels of bark beetles, especially Douglas-fir beetles, fir engraver beetles, and mountain and western pine beetles. A high endemic population of beetles can quickly develop into epidemic populations following wildfires. Thus, live fire-damaged trees in areas having root disease are probably more likely to be attacked by beetles than fire-damaged trees in areas without root disease.

Root diseases are usually slow killers of trees. Larger trees will often take decades to die since it takes years for root disease pathogens to grow throughout their root systems. Often, trees will have 25 percent or less of their root system remaining alive before crown symptoms are apparent. Trees in and adjacent to visible root disease centers likely have some portion of their root system infected and killed. Wildfire, coupled with higher than average fuel loads and resulting high burn intensity, will probably result in increased short and long term mortality in these areas relative to areas without root disease due to compounded stress associated with both fire damage and root disease infection. As in other cases resulting in vigor impacts, bark beetles and woodborers will usually be involved in causing mortality.

Areas of root disease infection are likely to be difficult to identify in recently burned areas. Some areas in the Blue Mountains have had root disease infection centers mapped in recent years. These include surveys done by Regional Forest Health Protection staff and Blue Mountains Pest Management Service Center staff. More common are insect and disease evaluations including information on root disease occurrence and severity that are descriptive at stand, planning area, or watershed level but usually do not include maps of root disease centers. Other information includes stand exam plots, special surveys, and Research studies that include root disease occurrence information.

Most of the northeastern portion of the 2002 Malheur Complex Fire, for example, burned in an area well known for having extensive Armillaria root disease. An Armillaria genetics study with principle cooperators at Oregon State University (Brennan Ferguson) and the USFS Pacific Northwest Forestry and Range Sciences Laboratory (Catherine Parks), has been underway in this area and documented the world's largest *Armillaria ostoyae* single genet in the Reynolds Creek/Grouse Knob/Mossy Gulch area. Nearly all of this large center is included within the perimeter of the fire. Two of five additional smaller genets also burned. While six genets were mapped, there is substantial additional root disease in this area as well, both within and adjacent to the burned area. Due to the high endemic levels of bark beetles, and increased fuels and fire damage to trees with pathogen-caused root damage, short-term and delayed-mortality levels are expected to be higher than usual in the perimeter of this burn. For other wildfires that occur in areas of root disease, the outcome would be similar, all other conditions being equal.

While root diseases may occur in other areas burned by 2002 wildfires in the Blue Mountains, incidence is believed to be minimal in most cases due to vegetation community type, or not noted during BMPMSC personnel field reviews in these areas in the past. District records, especially stand examinations, may provide some information. The influence of root diseases on short-term and delayed tree mortality should be taken into account during salvage marking of future wildfires.

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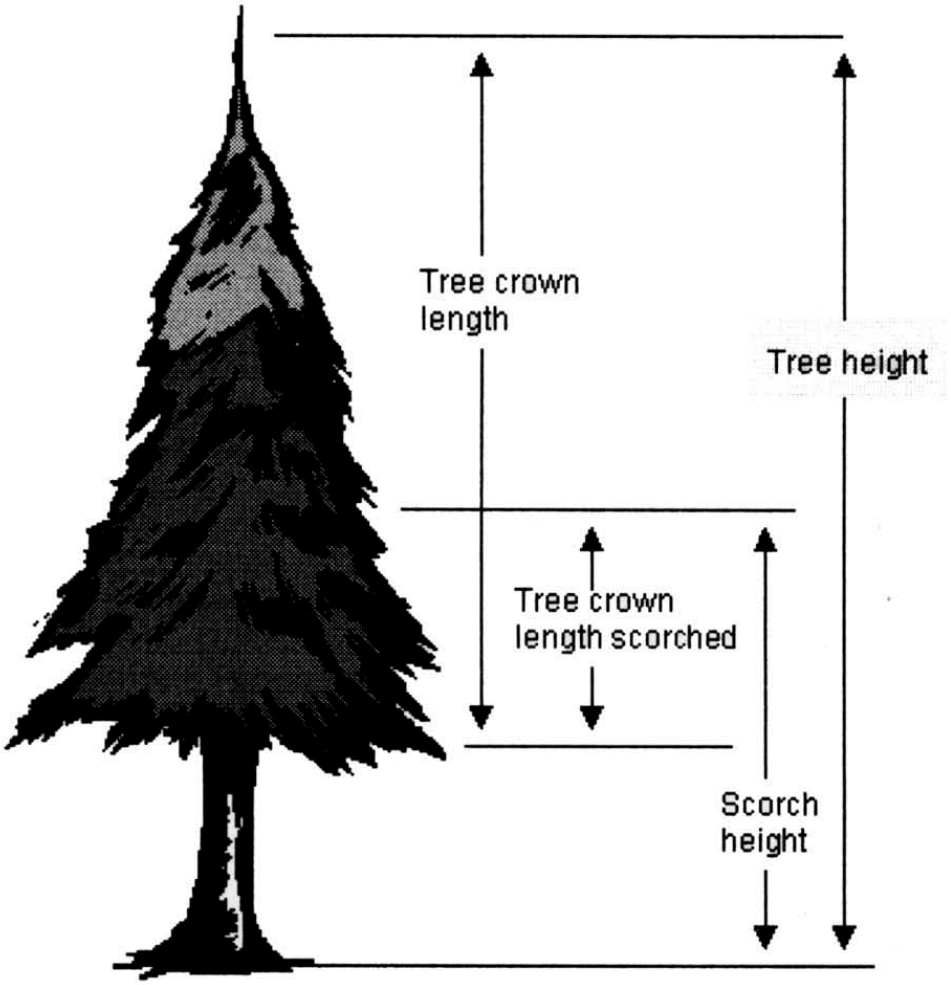
Appendix 1 – Tree Mortality Probability Tables

Probability of tree mortality can be calculated using fire mortality equations developed by Ryan and Reinhardt (1988) that use percentage of crown scorch and bark thickness as independent variables to predict the mortality probabilities for a given conifer species of given diameter. These equations, based on their implementation in First Order Fire Effects Model: FOFEM 4.0 (Reinhardt and others 1997) have been incorporated into the BehavePlus Fire Modeling System (Andrews and Bevins 1999) that we used to develop the following tables for ponderosa pine of given tree diameters: 5-in., 7-in., 9-in., 12-in., 15-in. 18-in., 21-in., 26-in., 32-in., and 40-in. The diameters selected represent the standardized tree classes, and their mid-point values, recognized in the Blue Mountains and included in the EVG Layer of the corporate National Forest system GIS databases. The diagram below (from the BehavePlus program) illustrates several of the terms referred to in the accompanying tables. Several of these terms are defined in the BehavePlus program as follows:



Scorch Height – The height above the ground that the temperature in the convection column reaches the lethal temperature to kill live crown foliage. This temperature is assumed to be 140 degrees Fahrenheit (60^o Celsius).

Tree Crown Length Scorched – The length of the tree crown that is scorched. It is calculated as **Scorch Height – (Tree Height – Live Crown Length)**. If **Scorch Height** is greater than the **Tree Height**, then the length of tree crown scorched equals the live crown length. **Tree Crown Length Scorched** is used to calculate percent of crown volume scorched, which is used to calculate tree mortality.

Tree Crown Volume Scorched – The percentage of the tree crown volume that is scorched is calculated from the length of tree crown scorched and the total crown length. It is used to calculate tree mortality.

Probability of Mortality – The probability of mortality is the likelihood that a tree will be killed by fire. Probability of mortality is based on bark thickness and percent of crown volume scorched which are derived from **Scorch Height**, **Tree Height**, crown ratio, species, and tree diameter. BehavePlus uses the mortality equations from "First Order Fire Effects Model: FOFEM 4.0 User's Guide (Reinhardt, and others 1997) to calculate these probabilities.

The tables were calculated assuming a standardized crown ratio of 0.5. This may over or underestimate the actual probability of tree mortality depending of the site quality and actual crown ratio of the tree being evaluated. However, it was assumed by using this crown ratio that it would approximate the "average" crown ratio of trees in most stands of the Blue Mountains. Limitations of time and space prevented us from producing tables of other crown ratios, or for other tree species. We did, however, use the BehavePlus tree mortality module to derive some of the crown scorch mortality probabilities and the total scorch height mortality probabilities for those factors in the rating system for all the species included.

The tables are displayed by total tree height in feet on the left side of the table, and with total scorch height in feet at the top of the table. It was assumed that measuring total scorch height in the field would be easier and more accurate than estimating crown volume scorched by field crews; therefore, total scorch height (assuming the 0.5 crown ratio) was the fire-injury variable included in these tables. The range of tree heights included in the tables for each of the diameters were approximated using height-diameter equations developed by Moore and others (1996) plus or minus several feet to extend the range to compensate for site quality differences not covered by the datasets used to develop the equations, including some that originated from northeastern Oregon and eastern Washington.

To use the table, three variables are needed: total tree height, total scorch height, and diameter at breast height. Select the table closest to the actual diameter of the tree. Enter the table with the total tree height on the left side of the table and the total scorch height at the top of the table. Where the two variables intersect in the body of the table, the probability of that tree dying will be given as a percentage.

Since most of the fires of 2002 in the Blue Mountains which prompted development of these tables occurred in stands dominated by ponderosa pines, mortality probability tables were only developed for that species. There was not sufficient time to develop similar tables for other species, although that may be done in the future. Also, time limited the development of tables for every possible diameter-class; therefore, we selected the diameter classes that are currently most meaningful in the management of

stands in the Blue Mountains. Moreover, after examining these results, we felt that mortality probabilities for the range of actual tree diameters falling between the tabled mortality classes could be approximated without appreciable error by using the table for the nearest diameter class to the tree's actual diameter.

Table 1. Probability of fire-induced mortality of a 5-inch (diameter breast height) Ponderosa Pine of varying tree heights based on total scorch height.[1]

5-INCH (DBH) PONDEROSA PINE MORTALITY
Probability of Mortality (%)

TOTAL TREE HEIGHT (ft)	TOTAL SCORCH HEIGHT (ft)																															
	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60
5																															
6																															
7																															
8																															
9																															
10																															
11																															
12																															
13																															
14																															
15	55	55	55	55	57	86	98	100																							
16	55	55	55	55	55	77	96	99	100																						
17	55	55	55	55	55	68	92	99	100																						
18	55	55	55	55	55	60	86	97	99	100																					
19	55	55	55	55	55	56	79	95	99	100																					
20	55	55	55	55	55	55	71	92	98	99	100																				
21	55	55	55	55	55	55	64	86	97	99	100																				
22	55	55	55	55	55	55	59	80	94	99	99	100																			
23	55	55	55	55	55	55	59	73	91	98	99	100																			
24	55	55	55	55	55	55	55	67	86	96	99	99	100																		
25	55	55	55	55	55	55	55	61	81	94	98	99	100																		
26	55	55	55	55	55	55	55	58	75	90	97	99	99	100																	
27	55	55	55	55	55	55	55	55	69	86	95	98	99	100																	
28	55	55	55	55	55	55	55	55	64	81	93	98	99	100	100																
29	55	55	55	55	55	55	55	55	60	76	90	97	99	99	100																
30	55	55	55	55	55	55	55	55	57	71	86	95	98	99	100	100															
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40																															

[1]Tree mortality values calculated with the *BehavePlus Fire Modeling System* (Andrews, P.L. and C.D. Bevins. 1999. Update and expansion of the BEHAVE Fire Modeling System. Fire Management Notes). Calculations assume 0.5 crown ratio for ponderosa pine, and tree heights of 15-30 feet. Probabilities

Table 2. Probability of fire-induced mortality of a 7-inch (diameter breast height) Ponderosa Pine of varying tree heights based on total scorch height.[1]

7-INCH (DBH) PONDEROSA PINE MORTALITY
Probability of Mortality (%)

TOTAL TREE HEIGHT (ft)	TOTAL SCORCH HEIGHT (ft)																															
	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60
25																															
26																															
27																															
28																															
29																															
30	41	41	41	41	41	41	41	41	43	58	78	91	97	99	99	99															
31	41	41	41	41	41	41	41	41	41	53	72	88	95	98	99	99	99														
32	41	41	41	41	41	41	41	41	41	48	66	83	93	97	99	99	99														
33	41	41	41	41	41	41	41	41	41	45	60	78	91	96	98	99	99	99													
34	41	41	41	41	41	41	41	41	41	43	55	73	87	95	98	99	99	99													
35	41	41	41	41	41	41	41	41	41	41	50	67	83	93	97	98	99	99	99												
36	41	41	41	41	41	41	41	41	41	41	47	61	78	90	96	98	99	99	99												
37	41	41	41	41	41	41	41	41	41	41	44	56	73	87	94	97	99	99	99	99											
38	41	41	41	41	41	41	41	41	41	41	42	52	68	83	92	96	99	99	99	99											
39	41	41	41	41	41	41	41	41	41	41	41	49	63	78	89	95	98	99	99	99	99										
40	41	41	41	41	41	41	41	41	41	41	41	46	58	74	86	93	97	98	99	99	99										
41	41	41	41	41	41	41	41	41	41	41	41	43	54	69	82	91	96	98	99	99	99	99									
42	41	41	41	41	41	41	41	41	41	41	41	42	50	64	78	89	94	97	98	99	99	99									
43	41	41	41	41	41	41	41	41	41	41	41	41	47	59	74	86	93	96	98	99	99	99	99								
44	41	41	41	41	41	41	41	41	41	41	41	41	45	55	69	82	91	95	97	99	99	99	99								
45	41	41	41	41	41	41	41	41	41	41	41	41	43	52	65	78	88	94	97	98	99	99	99	99							
46	41	41	41	41	41	41	41	41	41	41	41	41	42	49	61	74	85	92	96	98	99	99	99	99							
47	41	41	41	41	41	41	41	41	41	41	41	41	41	46	57	70	82	90	95	97	98	99	99	99	99						
48	41	41	41	41	41	41	41	41	41	41	41	41	41	44	53	66	78	88	93	96	98	99	99	99	99						
49	41	41	41	41	41	41	41	41	41	41	41	41	41	43	50	62	74	85	92	95	97	98	99	99	99	99					
50	41	41	41	41	41	41	41	41	41	41	41	41	41	42	48	58	71	82	90	94	97	98	99	99	99	99					
51																															
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[1]Tree mortality values calculated with the *BehavePlus Fire Modeling System* (Andrews, P.L. and C.D. Bevins. 1999. Update and expansion of the BEHAVE Fire Modeling System. Fire Management Notes). Calculations assume 0.5 crown ratio for ponderosa pine, and tree heights of 30-50 feet.

Table 3. Probability of fire-induced mortality of a 9-inch (diameter breast height) Ponderosa Pine of varying tree heights based on total scorch height.[1]

9-INCH (DBH) PONDEROSA PINE MORTALITY
Probability of Mortality (%)

TOTAL TREE HEIGHT (ft)	TOTAL SCORCH HEIGHT (ft)																														
	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60
35																															
36																															
37																															
38																															
39																															
40																															
41																															
42																															
43																															
44																															
45																															
46	30	30	30	30	30	30	30	30	30	30	30	30	31	37	49	64	78	88	93	96	98	98	99	99							
47	30	30	30	30	30	30	30	30	30	30	30	30	30	35	45	59	74	85	92	95	97	98	99	99	99						
48	30	30	30	30	30	30	30	30	30	30	30	30	30	33	41	54	69	81	90	94	97	98	99	99	99						
49	30	30	30	30	30	30	30	30	30	30	30	30	30	31	38	50	64	77	87	93	96	97	98	99	99	99					
50	30	30	30	30	30	30	30	30	30	30	30	30	30	31	36	46	59	73	84	91	95	97	98	99	99	99					
51	30	30	30	30	30	30	30	30	30	30	30	30	30	30	34	42	55	69	81	89	94	96	98	98	99	99	99				
52	30	30	30	30	30	30	30	30	30	30	30	30	30	30	32	40	51	64	77	86	92	95	97	98	99	99	99				
53	30	30	30	30	30	30	30	30	30	30	30	30	30	30	31	37	47	60	73	83	90	94	97	98	98	99	99	99			
54	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	35	44	56	69	80	88	93	96	97	98	99	99	99			
55	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	33	41	52	65	77	86	91	95	97	98	98	99	99	99		
56	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	32	38	48	61	73	83	90	94	96	97	98	99	99	99		
57	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	31	36	45	56	69	80	87	92	95	97	98	98	99	99	99	
58	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	34	42	53	65	76	85	91	94	96	98	98	99	99	99	
59	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	33	39	49	61	73	82	89	93	96	97	98	99	99	99	99
60	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	32	37	46	57	69	79	87	92	95	97	98	98	99	99	99
61																															
62																															
63																															
64																															
65																															
66																															
67																															
68																															
69																															
70																															

[1]Tree mortality values calculated with the *BehavePlus Fire Modeling System* (Andrews, P.L. and C.D. Bevins. 1999. Update and expansion of the BEHAVE Fire Modeling System. Fire Management Notes). Calculations assume 0.5 crown ratio for ponderosa pine, and tree heights of 46-60 feet.

Table 4. Probability of fire-induced mortality of a 12-inch (diameter breast height) Ponderosa Pine of varying tree heights based on total scorch height.[1]

12-INCH (DBH) PONDEROSA PINE MORTALITY
Probability of Mortality (%)

TOTAL TREE HEIGHT (ft)	TOTAL SCORCH HEIGHT (ft)																														
	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60
45																															
46																															
47																															
48																															
49																															
50																															
51																															
52																															
53																															
54	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	22	29	40	54	68	80	88	92	95	97	97	98	98			
55	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	21	27	37	50	64	76	85	91	94	96	97	98	98	98		
56	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	20	25	33	45	59	72	82	89	93	95	97	97	98	98		
57	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	23	30	41	54	68	79	87	92	95	96	97	98	98	98	
58	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	22	28	37	50	63	75	84	90	94	96	97	98	98	98	
59	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	21	26	34	46	59	71	81	88	92	95	96	97	98	98	98
60	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	20	24	31	42	54	67	78	86	91	94	96	97	98	98	98
61	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	23	29	38	50	63	74	83	89	93	95	97	97	98	98
62	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	21	27	35	46	59	70	80	87	92	94	96	97	98	98
63	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	20	25	32	42	54	66	77	85	90	93	95	97	97	98
64	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	20	23	30	39	50	62	74	82	88	92	95	96	97	98
65	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	22	28	36	46	58	70	79	86	91	94	96	97	97
66	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	21	26	33	43	54	66	76	84	89	93	95	96	97
67	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	20	24	31	39	50	62	73	81	87	92	94	96	97
68	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	20	23	28	36	47	58	69	78	85	90	93	95	96
69	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	22	27	34	43	54	65	75	83	88	92	94	96
70	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	21	25	31	40	51	62	72	80	87	91	94	95
71	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	20	24	29	37	47	58	69	78	85	89	93	95
72	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	20	22	27	34	44	54	65	75	82	88	91	94
73	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	21	26	32	41	51	61	71	80	86	90	93
74	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	21	24	30	38	47	58	68	77	84	89	92
75	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	20	23	28	35	44	54	65	74	81	87	91
76	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	22	26	33	41	51	61	71	79	85	89
77																															
78																															
79																															
80																															

[1]Tree mortality values calculated with the *BehavePlus Fire Modeling System* (Andrews, P.L. and C.D. Bevins. 1999. Update and expansion of the BEHAVE Fire Modeling System. Fire Management Notes). Calculations assume 0.5 crown ratio for ponderosa pine, and tree heights of 54-76 feet.

Table 4 (continued). Probability of fire-induced mortality of a 12-inch (diameter breast height) Ponderosa Pine of varying tree heights based on total scorch height.[1]

12-INCH (DBH) PONDEROSA PINE MORTALITY
Probability of Mortality (%)

TOTAL TREE HEIGHT (ft)	TOTAL SCORCH HEIGHT (ft)																														
	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110	112	114	116	118	120	122
45																															
46																															
47																															
48																															
49																															
50																															
51																															
52																															
53																															
54																															
55																															
56																															
57																															
58																															
59																															
60																															
61	98																														
62	98																														
63	98	98																													
64	98	98																													
65	98	98	98																												
66	98	98	98																												
67	67	98	98	98																											
68	97	98	98	98																											
69	97	97	98	98	98																										
70	97	97	98	98	98																										
71	96	97	97	98	98	98																									
72	96	97	97	98	98	98																									
73	95	96	97	98	98	98	98																								
74	94	96	97	97	98	98	98																								
75	93	95	96	97	98	98	98	98																							
76	93	95	96	97	97	98	98	98																							
77																															
78																															
79																															
80																															

[1]Tree mortality values calculated with the *BehavePlus Fire Modeling System* (Andrews, P.L. and C.D. Bevins. 1999. Update and expansion of the BEHAVE Fire Modeling System. Fire Management Notes). Calculations assume 0.5 crown ratio for ponderosa pine, and tree heights of 54-76 feet.

Table 5. Probability of fire-induced mortality of a 15-inch (diameter breast height) Ponderosa Pine of varying tree heights based on total scorch height.[1]

15-INCH (DBH) PONDEROSA PINE MORTALITY
Probability of Mortality (%)

TOTAL TREE HEIGHT (ft)	TOTAL SCORCH HEIGHT (ft)																													
	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60
55																															
56																															
57																															
58																															
59																															
60																															
61																															
62																															
63																															
64	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	13	15	20	28	38	50	62	73	82	88	91	94	95	96
65	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	15	19	25	34	46	58	70	79	86	90	93	95	96
66	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	14	17	23	31	42	54	66	76	83	88	92	94	95
67	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	13	16	21	28	38	49	62	72	81	87	91	93	95
68	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	13	15	19	26	34	45	57	69	78	85	89	92	94
69	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	14	18	23	31	42	53	65	75	82	88	91	93
70	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	14	17	21	29	38	49	61	71	79	86	90	93
71	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	13	14	20	26	35	45	57	68	77	83	88	92
72	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	13	15	18	24	32	42	53	64	73	81	87	90
73	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	14	17	22	29	38	49	60	70	78	85	89
74	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	13	16	20	27	35	45	56	67	75	82	87
75	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	13	15	19	24	32	42	52	63	72	80	86
76	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	13	14	18	23	29	38	49	59	69	77	84
77	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	14	17	21	27	35	45	55	66	74	81
78	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	13	16	19	25	32	42	52	62	71	79
79	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	13	15	18	23	30	38	48	59	68	76
80	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	13	14	17	21	28	35	45	55	65	73
81	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	14	16	20	25	33	42	51	61	70
82	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	13	15	19	24	30	38	48	58	67
83	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	13	15	18	22	28	36	45	54	64
84	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	14	17	20	26	33	42	51	61
85	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	13	16	19	24	31	39	48	57
86	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	13	15	18	22	28	36	45	54
87																															
88																															
89																															
90																															

[1]Tree mortality values calculated with the *BehavePlus Fire Modeling System* (Andrews, P.L. and C.D. Bevins. 1999. Update and expansion of the BEHAVE Fire Modeling System. Fire Management Notes). Calculations assume 0.5 crown ratio for ponderosa pine, and tree heights of 64-86 feet.

Table 5 (continued). Probability of fire-induced mortality of a 15-inch (diameter breast height) Ponderosa Pine of varying tree heights based on total scorch height.[1]

15-INCH (DBH) PONDEROSA PINE MORTALITY
Probability of Mortality (%)

TOTAL TREE HEIGHT (ft)	TOTAL SCORCH HEIGHT (ft)																														
	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110	112	114	116	118	120	122
55																															
56																															
57																															
58																															
59																															
60																															
61																															
62																															
63																															
64	96	97																													
65	96	97	97																												
66	96	97	97																												
67	96	96	97	97																											
68	95	96	97	97																											
69	95	96	96	97	97																										
70	94	95	96	97	97																										
71	94	95	96	96	97	97																									
72	93	94	96	96	97	97																									
73	92	94	95	96	96	97	97																								
74	91	93	95	96	96	97	97																								
75	90	92	94	95	96	96	97	97																							
76	88	91	93	95	96	96	97	97																							
77	86	90	93	94	95	96	96	97	97																						
78	85	89	92	94	95	96	96	97	97																						
79	83	87	91	93	94	95	96	96	97	97																					
80	80	86	89	92	94	95	96	96	97	97																					
81	78	84	88	91	93	94	95	96	96	97	97																				
82	75	82	86	90	92	94	95	96	96	97	97																				
83	72	79	85	89	91	93	95	96	96	96	97	97																			
84	70	77	83	87	90	93	94	95	96	96	97	97																			
85	66	74	81	86	89	92	93	95	96	96	96	97	97																		
86	63	72	78	84	88	91	93	94	95	96	96	97	97																		
87																															
88																															
89																															
90																															

[1]Tree mortality values calculated with the *BehavePlus Fire Modeling System* (Andrews, P.L. and C.D. Bevins. 1999. Update and expansion of the BEHAVE Fire Modeling System. Fire Management Notes). Calculations assume 0.5 crown ratio for ponderosa pine, and tree heights of 64-86 feet.

Table 6. Probability of fire-induced mortality of a 18-inch (diameter breast height) Ponderosa Pine of varying tree heights based on total scorch height.[1]

18-INCH (DBH) PONDEROSA PINE MORTALITY
Probability of Mortality (%)

TOTAL TREE HEIGHT (ft)	TOTAL SCORCH HEIGHT (ft)																													
	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60
70																															
71																															
72																															
73																															
74	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	9	11	14	19	26	35	46	57	67	75	82
75	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	9	11	13	18	24	32	42	53	63	72	80
76	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	9	10	12	16	21	29	38	49	59	69	77
77	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	10	12	15	20	26	35	45	56	66	74
78	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	9	11	14	18	24	32	41	52	62	71
79	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	9	10	13	16	22	29	38	48	58	68
80	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	9	10	12	15	20	26	35	44	55	64
81	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	9	11	14	18	24	32	41	51	61
82	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	9	11	13	17	22	29	38	47	57
83	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	9	10	12	16	20	27	35	44	54
84	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	9	10	12	14	19	24	32	41	50
85	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	9	11	13	17	22	29	37	47
86	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	9	10	13	16	21	27	35	43
87	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	9	10	12	15	19	25	32	40
88	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	9	10	11	14	18	23	29	37
89	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	9	11	13	16	21	27	34
90	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	9	10	12	15	19	25	32
91	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	9	10	12	14	18	23	29
92	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	9	9	11	13	17	21	27
93	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	9	10	13	16	20	25
94	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	9	10	12	15	18	23
95	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	9	10	11	14	17	21
96	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	9	11	13	16	20
97	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	9	10	12	15	19
98	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	9	10	12	14	17
99	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	9	10	11	13	16
100	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	9	11	12	15	
101																															
102																															
103																															
104																															
105																															

[1]Tree mortality values calculated with the *BehavePlus Fire Modeling System* (Andrews, P.L. and C.D. Bevins. 1999. Update and expansion of the BEHAVE Fire Modeling System. Fire Management Notes). Calculations assume 0.5 crown ratio for ponderosa pine, and tree heights of 74-100 feet.

Table 6 (continued). Probability of fire-induced mortality of a 18-inch (diameter breast height) Ponderosa Pine of varying tree heights based on total scorch height.[1]

18-INCH (DBH) PONDEROSA PINE MORTALITY
Probability of Mortality (%)

TOTAL TREE HEIGHT (ft)	TOTAL SCORCH HEIGHT (ft)																													
	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110	112	114	116	118	120	122
70																															
71																															
72																															
73																															
74	87	90	92	93	94	95	95																								
75	85	89	91	93	94	95	95	95																							
76	83	87	90	92	94	94	95	95																							
77	81	86	89	91	93	94	95	95	95																						
78	78	84	88	91	92	94	94	95	95																						
79	76	82	86	89	92	93	94	95	95	95																					
80	73	80	85	88	91	93	94	94	95	95																					
81	70	77	83	87	90	92	93	94	95	95	95																				
82	67	74	81	85	89	91	93	94	94	95	95																				
83	63	72	78	84	87	90	92	93	94	95	95	95																			
84	60	69	76	82	86	89	91	93	94	94	95	95																			
85	56	66	73	80	84	88	90	92	93	94	95	95	95																		
86	53	62	70	77	83	87	89	91	93	94	94	95	95																		
87	50	59	68	75	81	85	88	91	92	93	94	95	95	95																	
88	46	56	64	72	78	83	87	90	92	93	94	95	95	95																	
89	43	52	61	69	76	82	86	89	91	92	94	94	95	95	95																
90	40	49	58	66	74	80	84	88	90	92	93	94	95	95	95																
91	37	46	55	63	71	77	82	86	89	91	93	94	94	95	95	95															
92	34	43	52	60	68	75	81	85	88	90	92	93	94	95	95	95															
93	32	40	48	57	65	73	79	83	87	89	91	93	94	94	95	95	95														
94	29	37	45	54	62	70	76	81	85	88	91	92	93	94	95	95	95														
95	27	34	42	51	59	67	74	80	84	87	90	92	93	94	94	95	95	95													
96	25	32	39	48	56	64	72	78	82	86	89	91	92	93	94	95	95	95													
97	23	29	37	45	53	62	69	75	81	85	88	90	92	93	94	94	95	95	95												
98	22	27	34	42	50	59	66	73	79	83	86	89	91	92	93	94	95	95	95												
99	20	25	32	39	47	56	64	71	77	81	85	88	90	92	93	94	94	95	95	95											
100	19	24	30	37	44	53	61	68	74	80	84	87	89	91	93	93	94	95	95	95											
101																															
102																															
103																															
104																															
105																															

[1]Tree mortality values calculated with the *BehavePlus Fire Modeling System* (Andrews, P.L. and C.D. Bevins. 1999. Update and expansion of the BEHAVE Fire Modeling System. Fire Management Notes). Calculations assume 0.5 crown ratio for ponderosa pine, and tree heights of 74-100 feet.

Table 7. Probability of fire-induced mortality of a 21-inch (diameter breast height) Ponderosa Pine of varying tree heights based on total scorch height.[1]

21-INCH (DBH) PONDEROSA PINE MORTALITY
Probability of Mortality (%)

TOTAL TREE HEIGHT (ft)	TOTAL SCORCH HEIGHT (ft)																														
	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60
80																															
81																															
82																															
83																															
84	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7	8	11	14	19	25	33	42
85	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7	8	10	13	17	23	30	38
86	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7	8	9	12	15	21	27	35
87	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7	9	11	14	19	25	32
88	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7	8	10	13	17	23	30
89	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7	8	10	12	16	21	27
90	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7	9	11	14	19	25
91	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7	8	10	13	17	23
92	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7	8	10	12	16	21
93	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7	8	9	11	15	19
94	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7	9	11	14	18
95	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7	8	10	13	16
96	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7	8	9	12	15
97	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7	7	9	11	14
98	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7	8	10	13
99	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7	8	10	12
100	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7	8	9	11
101	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7	9	11
102	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7	8	10
103	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7	8	9
104	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7	8	9
105	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7	8
106	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7	8
107																															
108																															
109																															
110																															
111																															
112																															
113																															
114																															
115																															

[1]Tree mortality values calculated with the *BehavePlus Fire Modeling System* (Andrews, P.L. and C.D. Bevins. 1999. Update and expansion of the BEHAVE Fire Modeling System. Fire Management Notes). Calculations assume 0.5 crown ratio for ponderosa pine, and tree heights of 84-106 feet.

Table 7(continued). Probability of fire-induced mortality of a 21-inch (diameter breast height) Ponderosa Pine of varying tree heights based on total scorch height.[1]

21-INCH (DBH) PONDEROSA PINE MORTALITY
Probability of Mortality (%)

TOTAL TREE HEIGHT (ft)	TOTAL SCORCH HEIGHT (ft)																													
	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110	112	114	116	118	120	122
80																															
81																															
82																															
83																															
84	51	61	69	76	81	85	88	90	91	92	93	93																			
85	48	57	66	73	79	84	87	89	91	92	93	93	93																		
86	44	54	63	71	77	82	86	88	90	92	92	93	93																		
87	41	50	60	68	75	80	84	87	89	91	92	93	93	93																	
88	38	47	56	65	72	78	83	86	89	90	92	92	93	93																	
89	35	44	53	62	69	76	81	85	88	90	91	92	93	93	93																
90	32	40	49	58	66	73	79	83	86	89	91	92	92	93	93																
91	29	37	46	55	63	71	77	82	85	88	90	91	92	93	93	93															
92	27	34	43	52	60	68	75	80	84	87	89	91	92	92	93	93															
93	25	32	40	49	57	65	72	78	82	86	88	90	91	92	93	93	93														
94	23	29	37	45	54	62	70	76	81	84	87	89	91	92	92	93	93														
95	21	27	34	42	51	59	67	73	79	83	86	88	90	91	92	93	93	93													
96	19	25	32	39	48	56	64	71	77	81	85	87	89	91	92	93	93	93													
97	18	23	29	37	45	53	61	68	74	79	83	86	89	90	91	92	93	93	93												
98	16	21	27	34	42	50	58	66	72	78	82	85	88	90	91	92	93	93	93												
99	15	19	25	31	39	47	55	63	70	76	80	84	87	89	90	91	92	93	93	93											
100	14	18	23	29	36	44	52	60	67	73	78	82	86	88	90	91	92	93	93	93											
101	13	17	21	27	34	41	49	57	65	71	77	81	84	87	89	90	92	92	93	93	93										
102	12	15	20	25	31	38	46	54	62	69	74	79	83	86	88	90	91	92	93	93	93										
103	11	14	18	23	29	36	43	51	59	66	72	77	82	85	87	89	91	92	92	93	93	93									
104	11	13	17	21	27	33	41	48	56	63	70	75	80	84	86	88	90	91	92	93	93	93									
105	10	12	16	20	25	31	38	46	53	61	68	73	78	82	85	88	89	91	92	92	93	93	93								
106	10	12	15	18	23	29	35	43	50	58	65	71	76	81	84	87	89	90	91	92	93	93	93								
107																															
108																															
109																															
110																															
111																															
112																															
113																															
114																															
115																															

[1]Tree mortality values calculated with the *BehavePlus Fire Modeling System* (Andrews, P.L. and C.D. Bevins. 1999. Update and expansion of the BEHAVE Fire Modeling System. Fire Management Notes). Calculations assume 0.5 crown ratio for ponderosa pine, and tree heights of 84-106 feet.

Table 8. Probability of fire-induced mortality of a 26-inch (diameter breast height) Ponderosa Pine of varying tree heights based on total scorch height.[1]

26-INCH (DBH) PONDEROSA PINE MORTALITY
Probability of Mortality (%)

TOTAL TREE HEIGHT (ft)	TOTAL SCORCH HEIGHT (ft)																													
	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60
90																															
91																															
92																															
93																															
94	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	5	6	7	9	12	
95	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	5	5	7	8	11	
96	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	5	6	8	10	
97	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	5	6	7	9	
98	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	5	6	7	9	
99	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	5	5	6	8	
100	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	5	6	7	
101	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	5	6	7	
102	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	5	5	7	
103	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	5	6	
104	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	5	6	
105	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	5	6	
106	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	5	5	
107	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	5	
108	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	5	
109	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	5	
110	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	5	
111	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	
112	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	
113	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	
114	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	
115	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	
116	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	
117																															
118																															
119																															
120																															
121																															
122																															
123																															
124																															
125																															

[1]Tree mortality values calculated with the *BehavePlus Fire Modeling System* (Andrews, P.L. and C.D. Bevins. 1999. Update and expansion of the BEHAVE Fire Modeling System. Fire Management Notes). Calculations assume 0.5 crown ratio for ponderosa pine, and tree heights of 94-116 feet.

Table 8 (continued). Probability of fire-induced mortality of a 26-inch (diameter breast height) Ponderosa Pine of varying tree heights based on total scorch height.[1]

26-INCH (DBH) PONDEROSA PINE MORTALITY
Probability of Mortality (%)

TOTAL TREE HEIGHT (ft)	TOTAL SCORCH HEIGHT (ft)																													
	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110	112	114	116	118	120
90																														
91																														
92																														
93																														
94	16	21	27	35	43	51	59	67	73	77	81	84	86	88	89	89	89													
95	14	19	25	32	40	48	56	64	70	76	80	83	85	87	88	89	89	89												
96	13	17	23	29	37	45	53	61	68	73	78	82	84	86	88	89	89	89												
97	12	16	21	27	34	42	50	58	65	71	76	80	83	86	87	88	89	89	89											
98	11	15	19	25	31	39	47	55	62	69	74	79	82	85	87	88	89	89	89											
99	10	13	17	23	29	36	44	52	60	66	72	77	81	84	86	87	88	89	89	89										
100	9	12	16	21	27	33	41	49	57	64	70	75	79	82	85	87	88	89	89	89										
101	9	11	15	19	24	31	38	46	54	61	68	73	78	81	84	86	87	88	89	89	89									
102	8	10	13	17	22	28	35	43	51	58	65	71	76	80	83	85	87	88	89	89	89									
103	8	10	12	16	21	26	33	40	48	55	62	69	74	78	81	84	86	87	88	89	89	89								
104	7	9	11	15	19	24	30	37	45	53	60	66	72	76	80	83	85	87	88	89	89	89								
105	7	8	11	14	17	22	28	35	42	50	57	64	70	75	79	82	84	86	88	89	89	89	89							
106	6	8	10	12	16	20	26	32	39	47	54	61	67	73	77	81	83	85	87	88	89	89	89							
107	6	7	9	12	15	19	24	30	37	44	51	59	65	71	75	79	82	85	86	88	89	89	89	89						
108	6	7	9	11	14	17	22	28	34	41	49	56	63	68	73	78	81	84	86	87	88	89	89	89						
109	5	6	8	10	13	16	20	26	32	39	46	53	60	66	71	76	80	82	85	86	88	89	89	89	89					
110	5	6	7	9	12	15	19	24	30	36	43	50	57	64	69	74	78	81	84	86	87	88	89	89	89					
111	5	6	7	9	11	14	17	22	27	34	41	48	55	61	67	72	77	80	83	85	87	88	89	89	89	89				
112	5	6	7	8	10	13	16	20	25	31	38	45	52	59	65	70	75	79	82	84	86	87	88	89	89	89				
113	5	5	6	8	9	12	15	19	24	29	36	42	49	56	63	68	73	77	80	83	85	87	88	89	89	89	89			
114	4	5	6	7	9	11	14	17	22	27	33	40	47	54	60	66	71	76	79	82	84	86	87	88	89	89	89			
115	4	5	6	7	8	10	13	16	20	25	31	37	44	51	58	64	69	74	78	81	83	85	87	88	89	89	89	89		
116	4	5	5	6	8	10	12	15	19	23	29	35	42	48	55	61	67	72	76	80	82	84	86	87	88	89	89	89		
117																														
118																														
119																														
120																														
121																														
122																														
123																														
124																														
125																														

[1]Tree mortality values calculated with the *BehavePlus Fire Modeling System* (Andrews, P.L. and C.D. Bevins. 1999. Update and expansion of the BEHAVE Fire Modeling System. Fire Management Notes). Calculations assume 0.5 crown ratio for ponderosa pine, and tree heights of 94-116 feet.

Table 9. Probability of fire-induced mortality of a 32-inch (diameter breast height) Ponderosa Pine of varying tree heights based on total scorch height.[1]

32-INCH (DBH) PONDEROSA PINE MORTALITY
Probability of Mortality (%)

TOTAL TREE HEIGHT (ft)	TOTAL SCORCH HEIGHT (ft)																													
	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60
100																															
101																															
102																															
103																															
104	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4
105	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4
106	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4
107	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4
108	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
109	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
110	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
111	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
112	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
113	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
114	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
115	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
116	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
117	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
118	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
119	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
120	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
121	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
122	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
123	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
124	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
125	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
126	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
127	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
128	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
129	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
130	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
131	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
132	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
133	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
134	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
135																															

[1]Tree mortality values calculated with the *BehavePlus Fire Modeling System* (Andrews, P.L. and C.D. Bevins. 1999. Update and expansion of the BEHAVE Fire Modeling System. Fire Management Notes). Calculations assume 0.5 crown ratio for ponderosa pine, and tree heights of 104-134 feet.

Table 9 (continued). Probability of fire-induced mortality of a 32-inch (diameter breast height) Ponderosa Pine of varying tree heights based on total scorch height.[1]

32-INCH (DBH) PONDEROSA PINE MORTALITY
Probability of Mortality (%)

TOTAL TREE HEIGHT (ft)	TOTAL SCORCH HEIGHT (ft)																												
	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110	112	114	116	118	120
100																														
101																														
102																														
103																														
104	5	6	8	11	14	18	23	29	36	43	51	57	64	69	73	77	80	82	84	85	85	85								
105	5	6	8	10	13	16	21	27	33	40	48	55	61	67	72	76	79	81	83	84	85	85	85							
106	4	5	7	9	12	15	19	25	31	38	45	52	59	65	70	74	77	80	82	84	85	85	85							
107	4	5	6	8	11	14	18	23	29	35	42	49	56	62	68	72	76	79	81	83	84	85	85	85						
108	4	5	6	8	10	13	16	21	26	33	39	46	53	60	66	70	74	78	80	82	84	85	85	85						
109	4	5	6	7	9	12	15	19	24	30	37	44	51	57	63	68	73	76	79	81	83	84	85	85	85					
110	4	4	5	7	8	11	14	18	22	28	34	41	48	55	61	66	71	75	78	80	82	84	85	85	85					
111	3	4	5	6	8	10	13	16	21	26	32	38	45	52	58	64	69	73	77	79	82	83	84	85	85	85				
112	3	4	5	6	7	9	12	15	19	24	30	36	43	49	56	62	67	72	75	78	81	82	84	85	85	85				
113	3	4	4	5	7	8	11	14	17	22	27	34	40	47	53	60	65	70	74	77	80	82	83	84	85	85	85			
114	3	4	4	5	6	8	10	13	16	20	25	31	38	44	51	57	63	68	72	76	79	81	83	84	85	85	85			
115	3	3	4	5	6	7	9	12	15	19	24	29	35	42	48	55	61	66	70	74	77	80	82	83	84	85	85	85		
116	3	3	4	5	5	7	9	11	14	17	22	27	33	39	46	52	58	64	69	73	76	79	81	83	84	85	85	85		
117	3	3	4	4	5	6	8	10	13	16	20	25	31	37	43	50	56	62	67	71	75	78	80	82	83	84	85	85	85	
118	3	3	3	4	5	6	7	9	12	15	19	23	28	34	41	47	53	59	65	69	73	76	79	81	83	84	85	85	85	
119	3	3	3	4	5	6	7	9	11	14	17	21	26	32	38	45	51	57	63	67	72	75	78	80	82	83	84	85	85	85
120	3	3	3	4	4	5	6	8	10	13	16	20	25	30	36	42	49	55	60	66	70	74	77	79	81	83	84	85	85	85
121	3	3	3	4	4	5	6	7	9	12	15	18	23	28	34	40	46	52	58	63	68	72	76	78	80	82	84	84	85	85
122	3	3	3	3	4	5	6	7	9	11	14	17	21	26	32	37	44	5	56	61	66	71	74	77	80	81	83	84	85	85
123	3	3	3	3	4	4	5	7	8	10	13	16	20	24	29	35	41	48	54	59	64	69	73	76	79	81	82	84	84	85
124	3	3	3	3	4	4	5	6	8	9	12	15	18	23	27	33	39	45	51	57	62	67	71	75	77	80	82	83	84	85
125	3	3	3	3	4	4	5	6	7	9	11	14	17	21	26	31	37	43	49	55	60	65	69	73	76	79	81	82	84	84
126	3	3	3	3	3	4	5	5	7	8	10	13	16	19	24	29	35	40	46	52	58	63	68	72	75	78	80	82	83	84
127	3	3	3	3	3	4	4	5	6	8	9	12	15	18	22	27	32	38	44	50	56	61	66	70	74	77	79	81	83	84
128	3	3	3	3	3	4	4	5	6	7	9	11	14	17	21	25	30	36	42	48	54	59	64	68	72	75	78	80	82	83
129	3	3	3	3	3	3	4	5	6	7	8	10	13	16	19	24	28	34	40	46	51	57	62	67	71	74	77	79	81	83
130	3	3	3	3	3	3	4	4	5	6	8	10	12	15	18	22	27	32	37	43	49	55	60	65	69	73	76	78	80	82
131	3	3	3	3	3	3	4	4	5	6	7	9	11	14	17	20	25	30	35	41	47	53	58	63	67	71	74	77	79	81
132	3	3	3	3	3	3	4	4	5	6	7	8	10	13	16	19	23	28	33	39	45	50	56	61	66	70	73	76	78	80
133	3	3	3	3	3	3	3	4	5	5	6	8	10	12	14	18	22	26	31	37	42	48	54	59	64	68	72	75	77	80
134	3	3	3	3	3	3	3	4	4	5	6	7	9	11	14	17	20	25	29	35	40	46	51	57	62	66	70	73	76	79
135																														

[1]Tree mortality values calculated with the *BehavePlus Fire Modeling System* (Andrews, P.L. and C.D. Bevins. 1999. Update and expansion of the BEHAVE Fire Modeling System. Fire Management Notes). Calculations assume 0.5 crown ratio for ponderosa pine, and tree heights of 104-134 feet.

Table 9 (continued). Probability of fire-induced mortality of a 32-inch (diameter breast height) Ponderosa Pine of varying tree heights based on total scorch height.[1]

32-INCH (DBH) PONDEROSA PINE MORTALITY
Probability of Mortality (%)

TOTAL TREE HEIGHT (ft)	TOTAL SCORCH HEIGHT (ft)																										
	122	124	126	128	130	132	134	136	138	140	142	144	146	148	150	152	154	156	158	160	162	164	166	168	170	172	174
100																											
101																											
102																											
103																											
104																											
105																											
106																											
107																											
108																											
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114																											
115																											
116																											
117																											
118																											
119																											
120																											
121	85																										
122	85																										
123	85	85																									
124	85	85																									
125	85	85	85																								
126	85	85	85																								
127	85	85	85	85																							
128	84	85	85	85																							
129	84	85	85	85	85																						
130	83	84	85	85	85																						
131	83	84	85	85	85	85																					
132	82	83	84	85	85	85																					
133	81	83	84	85	85	85	85																				
134	81	82	83	84	85	85	85																				
135																											

[1]Tree mortality values calculated with the *BehavePlus Fire Modeling System* (Andrews, P.L. and C.D. Bevins. 1999. Update and expansion of the BEHAVE Fire Modeling System. Fire Management Notes). Calculations assume 0.5 crown ratio for ponderosa pine, and tree heights of 104-134 feet.

Table 10. Probability of fire-induced mortality of a 40-inch (diameter breast height) Ponderosa Pine of varying tree heights based on total scorch height.[1]

40-INCH (DBH) PONDEROSA PINE MORTALITY
Probability of Mortality (%)

TOTAL TREE HEIGHT (ft)	TOTAL SCORCH HEIGHT (ft)																														
	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60
115																															
116																															
117																															
118																															
119																															
120																															
121																															
122																															
123																															
124	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
125	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
126	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
127	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
128	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
129	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
130	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
131	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
132	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
133	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
134	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
135	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
136	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
137	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
138	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
139	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
140	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
141	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
142	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
143	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
144	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
145																															
146																															
147																															
148																															
149																															
150																															

[1]Tree mortality values calculated with the *BehavePlus Fire Modeling System* (Andrews, P.L. and C.D. Bevins. 1999. Update and expansion of the BEHAVE Fire Modeling System. Fire Management Notes). Calculations assume 0.5 crown ratio for ponderosa pine, and tree heights of 124-144 feet.

Table 10 (continued). Probability of fire-induced mortality of a 40-inch (diameter breast height) Ponderosa Pine of varying tree heights based on total scorch height.[1]

40-INCH (DBH) PONDEROSA PINE MORTALITY
Probability of Mortality (%)

TOTAL TREE HEIGHT (ft)	TOTAL SCORCH HEIGHT (ft)																													
	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110	112	114	116	118	120
115																														
116																														
117																														
118																														
119																														
120																														
121																														
122																														
123																														
124	2	2	2	2	3	3	4	5	6	7	9	11	14	17	22	26	32	37	43	49	55	60	64	68	71	74	76	78	79	80
125	2	2	2	2	3	3	4	4	5	7	8	10	13	16	20	25	30	35	41	47	52	58	62	66	70	73	75	77	79	80
126	2	2	2	2	2	3	3	4	5	6	8	9	12	15	19	23	28	33	39	44	50	55	60	65	68	72	74	76	78	79
127	2	2	2	2	2	3	3	4	5	6	7	9	11	14	17	21	26	31	36	42	48	53	58	63	67	70	73	76	77	79
128	2	2	2	2	2	3	3	4	4	5	7	8	10	13	16	20	24	29	34	40	46	51	56	61	65	69	72	75	77	78
129	2	2	2	2	2	3	3	3	4	5	6	8	9	12	15	18	22	27	32	38	43	49	54	59	64	67	71	73	76	78
130	2	2	2	2	2	2	3	3	4	5	6	7	9	11	14	17	21	25	30	36	41	47	52	57	62	66	69	72	75	77
131	2	2	2	2	2	2	3	3	4	4	5	7	8	10	13	16	19	24	28	34	39	45	50	55	60	64	68	71	74	76
132	2	2	2	2	2	2	3	3	3	4	5	6	8	9	12	15	18	22	27	32	37	42	48	53	58	62	66	70	73	75
133	2	2	2	2	2	2	3	3	3	4	5	6	7	9	11	14	17	20	25	30	35	40	46	51	56	61	65	68	71	74
134	2	2	2	2	2	2	2	3	3	4	4	5	7	8	10	13	16	19	23	28	33	38	44	49	54	59	63	67	70	73
135	2	2	2	2	2	2	2	3	3	4	4	5	6	8	9	12	14	18	22	26	31	36	41	47	52	57	61	65	69	72
136	2	2	2	2	2	2	2	3	3	3	4	5	6	7	9	11	13	17	20	24	29	34	39	45	50	55	59	64	67	70
137	2	2	2	2	2	2	2	2	3	3	4	5	6	7	8	10	13	15	19	23	27	32	37	43	48	53	58	62	66	69
138	2	2	2	2	2	2	2	2	3	3	4	4	5	6	8	9	12	14	18	21	25	30	35	40	46	51	56	60	64	68
139	2	2	2	2	2	2	2	2	3	3	3	4	5	6	7	9	11	13	16	20	24	28	33	38	44	49	54	58	63	66
140	2	2	2	2	2	2	2	2	3	3	3	4	5	6	7	8	10	12	15	19	22	27	31	36	42	47	52	56	61	65
141	2	2	2	2	2	2	2	2	2	3	3	4	4	5	6	8	9	12	14	17	21	25	30	34	40	45	50	55	59	63
142	2	2	2	2	2	2	2	2	2	3	3	4	4	5	6	7	9	11	13	16	20	23	28	33	38	43	48	53	57	61
143	2	2	2	2	2	2	2	2	2	3	3	3	4	5	6	7	8	10	12	15	18	22	26	31	36	41	46	51	55	60
144	2	2	2	2	2	2	2	2	2	2	3	3	4	4	5	6	8	9	12	14	17	21	25	29	34	39	44	49	53	58
145																														
146																														
147																														
148																														
149																														
150																														

[1]Tree mortality values calculated with the *BehavePlus Fire Modeling System* (Andrews, P.L. and C.D. Bevins. 1999. Update and expansion of the BEHAVE Fire Modeling System. Fire Management Notes). Calculations assume 0.5 crown ratio for ponderosa pine, and tree heights of 124-144 feet.

Table 10 (continued). Probability of fire-induced mortality of a 40-inch (diameter breast height) Ponderosa Pine of varying tree heights based on total scorch height.[1]

40-INCH (DBH) PONDEROSA PINE MORTALITY
Probability of Mortality (%)

TOTAL TREE HEIGHT (ft)	TOTAL SCORCH HEIGHT (ft)																										
	122	124	126	128	130	132	134	136	138	140	142	144	146	148	150	152	154	156	158	160	162	164	166	168	170	172	174
115																											
116																											
117																											
118																											
119																											
120																											
121																											
122	81																										
123	81	81																									
124	81	81																									
125	81	81	81																								
126	80	81	81																								
127	80	81	81	81																							
128	79	80	81	81																							
129	79	80	81	81	81																						
130	78	79	80	81	81																						
131	78	79	80	81	81	81																					
132	77	78	80	80	81	81																					
133	76	78	79	80	81	81	81																				
134	75	77	78	80	80	81	81																				
135	74	76	78	79	80	81	81	81																			
136	73	75	77	79	80	80	81	81																			
137	72	74	76	78	79	80	81	81	81																		
138	71	73	75	77	79	80	80	81	81																		
139	69	72	75	76	78	79	80	81	81	81																	
140	68	71	74	76	77	79	80	80	81	81																	
141	67	70	73	75	77	78	79	80	81	81	81																
142	65	69	71	74	76	77	79	80	80	81	81																
143	64	67	70	73	75	77	78	79	80	81	81	81															
144	62	66	69	72	74	76	78	79	80	80	81	81															
145																											
146																											
147																											
148																											
149																											
150																											

[1]Tree mortality values calculated with the *BehavePlus Fire Modeling System* (Andrews, P.L. and C.D. Bevins. 1999. Update and expansion of the BEHAVE Fire Modeling System. Fire Management Notes). Calculations assume 0.5 crown ratio for ponderosa pine, and tree heights of 124-144 feet.

Appendix 2 – Criteria For Determining Rating Ranges For Decision Classes

Ponderosa Pine Young and Immature Trees

(Survival One Year After Fire)

Small Trees (< 16 in. dbh):

	Composite Rating Ranges By Survival Decision Classes		
	High	**Moderate**	**Low**
Season of Fire	0-2	1-2	1-2
Pre-Fire Vigor, Growth Rate, and Site Quality	0-0	0-1	0-1
Arrangement/Distribution of Down Woody Material	0-0	0-1	1-1
Dwarf Mistletoe Occurrence	0-1	1-1	2-2
Root Disease Occurrence	N/A	N/A	N/A
Bark Beetle Pressure	1-1	1-2	2-3
Crown Volume Scorch	0-2	4-4	6-6
Bole Scorch	0-1	2-2	3-3
Total Scorch Height	1-1	1-2	2-3
Duff Consumption	0-0	0-0	0-0
Totals	2-8	10-15	17-21

Large Trees (> 16 in. dbh):

	Composite Rating Ranges By Survival Decision Classes		
	High	**Moderate**	**Low**
Season of Fire	0-2	1-2	1-2
Pre-Fire Vigor, Growth Rate, and Site Quality	0-1	0-1	0-1
Arrangement/Distribution of Down Woody Material	0-0	1-1	1-1
Dwarf Mistletoe Occurrence	0-1	1-2	2-2
Root Disease Occurrence	N/A	N/A	N/A
Bark Beetle Pressure	1-1	1-2	2-3
Crown Volume Scorch	0-2	4-4	6-6
Bole Scorch	0-1	2-2	3-3
Total Scorch Height	1-1	1-2	2-3

Duff Consumption	0-0	2-2	4-4
Totals	2-9	13-18	21-25

Ponderosa Pine Mature and Overmature Trees

(Survival One Year After Fire)

	Composite Rating Ranges By Survival Decision Classes		
	High	**Moderate**	**Low**
Season of Fire	0-2	1-2	1-2
Pre-Fire Vigor, Growth Rate, and Site Quality	0-0	0-1	0-1
Arrangement/Distribution of Down Woody Material	0-0	1-1	1-1
Dwarf Mistletoe Occurrence	0-0	0-1	2-2
Root Disease Occurrence	N/A	N/A	N/A
Bark Beetle Pressure	1-1	1-2	2-3
Crown Volume Scorch	0-2	4-4	4-6
Bole Scorch	0-2	2-2	3-3
Total Scorch Height	1-1	1-2	2-3
Duff Consumption	0-0	0-3	6-6
Totals	2-8	10-18	21-27

Ponderosa Pine Mature and Overmature Trees

(Survival Beyond One Year After Fire)

	Composite Rating Ranges By Survival Decision Classes		
	High	**Moderate**	**Low**
Season of Fire	0-2	1-2	1-2
Pre-Fire Vigor, Growth Rate, and Site Quality	0-0	0-1	0-1
Arrangement/Distribution of Down Woody Material	0-0	1-1	1-1
Dwarf Mistletoe Occurrence	0-0	0-1	2-2
Root Disease Occurrence	N/A	N/A	N/A
Bark Beetle Pressure	1-1	1-2	2-3

Crown Volume Scorch	0-1	1-1	2-3
Bole Scorch	0-1	2-2	2-3
Total Scorch Height	1-1	1-2	2-3
Duff Consumption	0-0	0-0	3-6
Totals	2-6	7-12	15-24

Douglas-fir Young and Immature Trees

(Survival One Year After Fire)

	Composite Rating Ranges By Survival Decision Classes		
	High	**Moderate**	**Low**
Season of Fire	0-2	1-2	1-2
Pre-Fire Vigor, Growth Rate, and Site Quality	0-0	0-1	0-1
Arrangement/Distribution of Down Woody Material	0-0	1-1	1-1
Dwarf Mistletoe Occurrence	0-0	0-1	2-2
Root Disease Occurrence	0-0	0-1	1-1
Bark Beetle Pressure	1-1	1-2	2-3
Crown Volume Scorch	0-2	1-2	3-4
Bole Scorch	0-1	1-2	3-4
Total Scorch Height	1-1	1-2	2-3
Duff Consumption	0-0	2-2	2-4
Totals	2-7	8-16	17-25

Douglas-fir Mature and Overmature Trees

(Survival One Year After Fire)

	Composite Rating Ranges By Survival Decision Classes		
	High	**Moderate**	**Low**
Season of Fire	0-2	1-2	1-2

Pre-Fire Vigor, Growth Rate, and Site Quality	0-0	0-1	0-1
Arrangement/Distribution of Down Woody Material	0-0	1-1	1-1
Dwarf Mistletoe Occurrence	0-0	0-1	2-2
Root Disease Occurrence	0-0	0-1	1-1
Bark Beetle Pressure	1-1	1-2	2-3
Crown Volume Scorch	0-2	2-2	4-8
Bole Scorch	0-1	1-2	2-4
Total Scorch Height	1-1	2-2	3-3
Duff Consumption	0-3	3-3	3-6
Totals	2-10	11-17	19-31

Engelmann Spruce All Size Classes of Trees

(Survival One Year After Fire)

	Composite Rating Ranges By Survival Decision Classes		
	High	**Moderate**	**Low**
Season of Fire	0-2	1-2	1-2
Pre-Fire Vigor, Growth Rate, and Site Quality	0-0	0-1	0-1
Arrangement/Distribution of Down Woody Material	0-0	1-1	1-1
Dwarf Mistletoe Occurrence	N/A	N/A	N/A
Root Disease Occurrence	N/A	N/A	N/A
Bark Beetle Pressure	1-1	1-2	2-3
Crown Volume Scorch	0-0	3-3	6-12
Bole Scorch	0-3	3-3	6-9
Total Scorch Height	0-0	0-1	2-3
Duff Consumption	0-0	0-1	1-2
Totals	1-6	9-14	19-33

Lodgepole Pine All Size Classes of Trees

(Survival One Year After Fire)

	Composite Rating Ranges By Survival Decision Classes		
	High	**Moderate**	**Low**
Season of Fire	0-2	1-2	1-2
Pre-Fire Vigor, Growth Rate, and Site Quality	0-0	0-1	0-1
Arrangement/Distribution of Down Woody Material	0-0	1-1	1-1
Dwarf Mistletoe Occurrence	0-0	0-1	2-2
Root Disease Occurrence	N/A	N/A	N/A
Bark Beetle Pressure	1-1	1-2	2-3
Crown Volume Scorch	0-0	1-1	2-3
Bole Scorch	0-3	3-6	9-9
Total Scorch Height	1-1	1-2	2-3
Duff Consumption	1-1	1-2	2-4
Totals	3-8	9-18	21-28

Western Larch All Size Classes of Trees

(Survival One Year After Fire)

	Composite Rating Ranges By Survival Decision Classes		
	High	**Moderate**	**Low**
Season of Fire	0-2	1-2	2-2
Pre-Fire Vigor, Growth Rate, and Site Quality	0-0	0-1	0-1
Arrangement/Distribution of Down Woody Material	0-0	1-1	1-1
Dwarf Mistletoe Occurrence	1-1	1-2	2-2
Root Disease Occurrence	N/A	N/A	N/A
Bark Beetle Pressure	N/A	N/A	N/A
Crown Volume Scorch	0-2	3-3	4-4
Bole Scorch	N/A	N/A	N/A
Total Scorch Height	1-1	1-2	3-3
Duff Consumption	0-0	0-2	2-4

Totals	2-6	7-13	14-17

Grand Fir and White Fir All Size Classes of Trees

(Survival One Year After Fire)

	Composite Rating Ranges By Survival Decision Classes		
	High	**Moderate**	**Low**
Season of Fire	0-2	1-2	1-2
Pre-Fire Vigor, Growth Rate, and Site Quality	0-0	0-1	0-1
Arrangement/Distribution of Down Woody Material	0-0	0-0	0-1
Dwarf Mistletoe Occurrence	N/A	N/A	N/A
Root Disease Occurrence	0-0	0-1	0-1
Bark Beetle Pressure	1-1	1-2	1-3
Crown Volume Scorch	0-0	0-1	2-4
Bole Scorch	0-0	1-1	3-9
Total Scorch Height	1-1	1-2	2-3
Duff Consumption	0-0	1-1	2-6
Totals	2-4	5-10	11-30

Subalpine Fir All Size Classes of Trees

(Survival One Year After Fire)

	Composite Rating Ranges By Survival Decision Classes		
	High	**Moderate**	**Low**
Season of Fire	0-2	1-2	1-2
Pre-Fire Vigor, Growth Rate, and Site Quality	0-0	0-1	0-1
Arrangement/Distribution of Down Woody Material	0-0	0-0	0-1
Dwarf Mistletoe Occurrence	N/A	N/A	N/A

Root Disease Occurrence	0-0	0-1	0-1
Bark Beetle Pressure	1-0	1-2	1-3
Crown Volume Scorch	0-0	0-1	2-4
Bole Scorch	0-0	1-1	3-9
Total Scorch Height	1-1	1-2	2-3
Duff Consumption	0-1	1-1	2-6
Totals	2-4	5-10	11-30

Western White Pine Young and Immature Trees

(Survival One Year After Fire)

	Composite Rating Ranges By Survival Decision Classes		
	High	**Moderate**	**Low**
Season of Fire	0-2	1-2	1-2
Pre-Fire Vigor, Growth Rate, and Site Quality	0-0	0-1	0-1
Arrangement/Distribution of Down Woody Material	0-0	1-1	1-1
Dwarf Mistletoe Occurrence	N/A	N/A	N/A
Root Disease Occurrence	N/A	N/A	N/A
Bark Beetle Pressure	1-1	2-2	3-3
Crown Volume Scorch	0-0	0-2	4-8
Bole Scorch	N/A	N/A	N/A
Total Scorch Height	0-1	2-2	2-3
Duff Consumption	0-0	0-0	1-2
Totals	1-4	6-10	12-20

Western White Pine Mature and Overmature Trees

(Survival One Year After Fire)

	Composite Rating Ranges By Survival Decision Classes		
	High	**Moderate**	**Low**
Season of Fire	0-2	1-2	1-2
Pre-Fire Vigor, Growth Rate, and Site Quality	0-0	0-1	0-1
Arrangement/Distribution of Down Woody Material	0-0	1-1	1-1
Dwarf Mistletoe Occurrence	N/A	N/A	N/A
Root Disease Occurrence	N/A	N/A	N/A
Bark Beetle Pressure	1-1	1-2	2-3
Crown Volume Scorch	0-4	4-6	8-8
Bole Scorch	N/A	N/A	N/A
Total Scorch Height	1-1	2-2	3-3
Duff Consumption	0-0	0-0	1-2
Totals	2-8	9-14	16-20

Factors Affecting Survival of Fire Injured Trees: A Rating System For Determining Relative Probability of Survival of Conifers in the Blue and Wallowa Mountains

AMENDMENT 1

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June 26, 2003

Report No. BMPMSC-03-01 Amend. 1

This amendment documents changes to the parent document for grand fir/white fir, and lodgepole pine. The parent document is Report No. BMPMSC-03-01 dated November 25, 2002.

Preliminary field validation of the rating system on the Monument Fire on June 25, 2003 found that the rating system as described in the parent document worked relatively well for the species validated: immature and mature/overmature ponderosa pine, immature and mature/overmature Douglas-fir, white fir under 25 inches dbh, and western larch at various stages of maturity. Although we did not examine a complete range of conditions for lodgepole pine and mature/overmature white fir, we found that the lodgepole pine system tended to underestimate probability of tree mortality more times than not, and the grand fir/white fir system tended to overestimate probability of tree mortality for the mature or overmature grand firs; i.e., trees larger than roughly 25 inches dbh.

We have attempted to correct these problems in the rating systems included in this amendment. The mature/overmature grand and white fir rating system is entirely new, and is based in large part on running the Behave Plus model using a data set for grand fir from the Blue Mountains (southern Umatilla National Forest) to provide regression estimators for tree height based on diameter to use in the Behave Plus model. This rating system should be used on larger trees that are 25 inches and larger in diameter. We provide rating criteria for 30-40 inch trees. Trees 25-29 inches in diameter should use the 30-inch tree criteria; trees larger than 40 inches should use the 40-inch criteria. The original rating system for grand and white fir should continue to be used on all trees of these species under 25 inches in diameter.

The lodgepole pine rating system included in this amendment was modified from the original by adjusting the distribution of rating scores for individual criteria for the Decision Classes, and also increasing the penalty scores for the duff consumption criteria. We believe both these rating systems provide more accurate probability of tree mortality determinations than the original rating systems.

Grand Fir and White Fir *(Mature and Overmature Trees ≥ 30 in. dbh)*

(Use nearest diameter below to diameter of tree being evaluated)

RATING FACTOR

7. **Crown Volume Scorch** (Reinhardt and Ryan 1988; Ryan and Reinhardt 1988; assumes 50% pre-fire live crown ratio)

a. No visible scorching (0)

b. For trees **30 in.** dbh :
Crown volume scorched between 0-64% (mortality probability 6-35.0%) (1)
Crown volume scorched between 65-83% (mortality probability 36-71%) (2)
Crown volume scorched between 84-100% (mortality probability 72-93%) (3)

c. For trees **32 in.** dbh :
Crown volume scorched between 0-67% (mortality probability 5-38%) (1)
Crown volume scorched between 68-85% (mortality probability 39-71%) (2)
Crown volume scorched between 86-100% (mortality probability 72-92%) (3)

d. For trees **34 in.** dbh :
Crown volume scorched between 0-68% (mortality probability 5-36%) (1)
Crown volume scorched between 69-85% (mortality probability 37-68%) (2)
Crown volume scorched between 86-100% (mortality probability 69-91%) (3)

e. For trees **36 in.** dbh :
Crown volume scorched between 0-68% (mortality probability 4-33%) (1)
Crown volume scorched between 69-86% (mortality probability 34-69%) (2)
Crown volume scorched between 87-100% (mortality probability 70-90%) (3)

f. For trees **38 in.** dbh :
Crown volume scorched between 0-71% (mortality probability 4-35%) (1)
Crown volume scorched between 72-87% (mortality probability 36-69%) (2)
Crown volume scorched between 88-100% (mortality probability 70-89%) (3)

g. For trees ≥ **40 in.** dbh :
Crown volume scorched between 0-71% (mortality probability 3-34%) (1)
Crown volume scorched between 72-89% (mortality probability 35-71%) (2)
Crown volume scorched between 90-100% (mortality probability 72-88%) (3)

8. **Bole Char at Ground Level** (Scott and others 1996, with modification)
(*To ensure accurate interpretation of the following criteria, the cambium at the root collar should be sampled from 4 areas of equally spaced quadrants from around the bole on a subsample of trees. The numbers enclosed in parentheses following the bole char criterion are the numbers of sampled quadrants with* ***dead*** *cambium out of the 4 quadrants sampled*)

a. No charring present on bole or charring, if present, is light or only at surface (0)
b. <20% of base of bole deeply charred (0 or 1 quadrant with dead cambium) (1)
c. 20-60% of base of bole deeply charred (1 or 2 quadrants with dead cambium) (2)

d. 60-80% of base of bole deeply charred (2 or 3 quadrants with dead cambium) (3)
e. >80% of base of bole deeply charred (3 or 4 quadrants with dead cambium) (4)

9. **Total Scorch Height** (Reinhardt and Ryan 1988; Ryan and Reinhardt 1988)
(Use nearest diameter below to diameter of tree being evaluated)

a. No visible scorching (0)

b. For trees **30 in.** dbh :
Total scorch height between 0-74 ft. (mortality probability 6-35.0%) (1)
Total scorch height between 75-84 ft. (mortality probability 36-71%) (2)
Total scorch height between 85-106 ft. (mortality probability 72-93%) (3)

c. For trees **32 in.** dbh :
Total scorch height between 0-80 ft. (mortality probability 5-38%) (1)
Total scorch height between 81-90 ft. (mortality probability 39-71%) (2)
Total scorch height between 91-112 ft. (mortality probability 72-92%) (3)

d. For trees **34 in.** dbh :
Total scorch height between 0-84 ft. (mortality probability 5-36%) (1)
Total scorch height between 85-94 ft. (mortality probability 37-68%) (2)
Total scorch height between 95-116 ft. (mortality probability 69-91%) (3)

e. For trees **36 in.** dbh :
Total scorch height between 0-88 ft. (mortality probability 4-33%) (1)
Total scorch height between 89-100 ft. (mortality probability 34-69%) (2)
Total scorch height between 101-122 ft. (mortality probability 70-90%) (3)

f. For trees **38 in.** dbh :
Total scorch height between 0-94 ft. (mortality probability 4-35%) (1)
Total scorch height between 95-106 ft. (mortality probability 36-69%) (2)
Total scorch height between 107-128 ft. (mortality probability 70-89%) (3)

g. For trees ≥ **40 in.** dbh :
Total scorch height between 0-98 ft. (mortality probability 3-34%) (1)
Total scorch height between 99-112 ft. (mortality probability 35-71%) (2)
Total scorch height between 113-134 ft. (mortality probability 72-88%) (3)

10. **Duff Consumption** (Ryan 1990; Ryan and Frandsen 1991; Ryan and Noste 1985)

a. No leaf litter or duff scorched or consumed (0)
b. Leaf litter charred or consumed; upper duff charred, but not altered over entire depth. (1)
c. Leaf litter consumed; duff deeply charred or consumed, but underlying mineral soil is not visibly altered. (2)
d. Litter and duff completely consumed, and top layer of mineral soil visibly altered, often reddish. (3)

Subtotal Rating Score for Part B: _____

Composite Rating Score Part A+B: _____

Suggested Decision Classes:

(Refer to Appendix 2 For Rating Range Determinations)

Mature and Overmature Grand Fir and White Fir

High Probability of Tree Surviving = Composite Rating Score Ranging from **2-12**
Moderate Probability of Tree Surviving = Composite Rating Score Ranging from **13-16**
Low Probability of Tree Surviving = Composite Rating Score Ranging from **17-21**

Grand Fir and White Fir All Size Classes of Trees

(*Survival One Year After Fire*)

	Composite Rating Ranges By Survival Decision Classes		
	High	**Moderate**	**Low**
Season of Fire	0-2	2-2	2-2
Pre-Fire Vigor, Growth Rate, and Site Quality	0-1	1-1	1-1
Arrangement/Distribution of Down Woody Material	0-1	1-1	1-1
Dwarf Mistletoe Occurrence	N/A	N/A	N/A
Root Disease Occurrence	0-1	1-1	1-1
Bark Beetle Pressure	1-2	2-3	3-3
Crown Volume Scorch	1-2	2-2	2-3
Bole Scorch	0-1	1-2	3-4
Total Scorch Height	0-1	2-2	2-3
Duff Consumption	0-1	1-2	2-3
Totals	2-12	13-16	17-21

Lodgepole Pine *(All Size Classes except as noted)*

(This page replaces pages 17 and 18 in the original document)

RATING FACTOR

7. **Crown Volume Scorch** (Ryan and Reinhardt 1989; Weatherby and others 2001)
   a. No visible scorching (0)
   b. Crown volume scorched is ≤20% (63% mortality all trees ≤9") (1)
   c. Crown volume scorched is 20-50% (80.0% mortality for 9" trees) (2)
   d. Crown volume scorched is >50% (>80% mortality for 9" trees) (3)

8. **Bole/Root Char** (Weatherby and others 2001)
   a. No visible char (0)
   b. <30% of bole circumference blackened (20% mortality) (3)
   c. 30-60% of bole circumference blackened (40% mortality) (6)
   d. >60% of bole circumference blackened (≥50% mortality) (9)

9. **Total Scorch Height** (Reinhardt and Ryan 1988; Ryan and Reinhardt 1988)
   (Use nearest diameter below to diameter of tree being evaluated)
   a. For trees **9 in.** dbh :
      Total scorch height between 0-28 ft. (mean mortality probability 63.0%) (1)
      Total scorch height between 29-38 ft. (mean mortality probability 72.2%) (2)
      Total scorch height between 39-58 ft. (mean mortality probability 98.4%) (3)

   b. For trees **15 in.** dbh :
      Total scorch height between 0-40 ft. (mean mortality probability 44.0%) (1)
      Total scorch height between 41-56 ft. (mean mortality probability 65.9%) (2)
      Total scorch height between 57-80 ft. (mean mortality probability 97.5%) (3)

   c. For trees **21 in.** dbh :
      Total scorch height between 0-46 ft. (mean mortality probability 30.0%) (1)
      Total scorch height between 47-64 ft. (mean mortality probability 54.7%) (2)
      Total scorch height between 65-90 ft. (mean mortality probability 96.0%) (3)

10. **Duff Consumption** (Ryan 1990; Ryan and Frandsen 1991; Ryan and Noste 1985)
    a. No leaf litter or duff scorched or consumed (0)
    b. Leaf litter charred or consumed; upper duff charred, but not altered over entire depth. (4)
    c. Leaf litter consumed; duff deeply charred or consumed, but underlying mineral soil is not visibly altered. (5)
    d. Litter and duff completely consumed, and top layer of mineral soil visibly altered, often reddish. (6)

Subtotal Rating Score for Part B: _____

Composite Rating Score Part A+B: _____

Suggested Decision Classes:

(Refer to Appendix 2 For Rating Range Determinations)

All Size Classes of Lodgepole Pine

High Probability of Tree Surviving = Composite Rating Score Ranging from **2-5**
Moderate Probability of Tree Surviving = Composite Rating Score Ranging from **6-10**
Low Probability of Tree Surviving = Composite Rating Score Ranging from **14-30**

Lodgepole Pine All Size Classes of Trees

(*Survival One Year After Fire*)

	Composite Rating Ranges By Survival Decision Classes		
	High	**Moderate**	**Low**
Season of Fire	0-2	1-2	1-2
Pre-Fire Vigor, Growth Rate, and Site Quality	0-0	0-1	1-1
Arrangement/Distribution of Down Woody Material	0-0	0-1	1-1
Dwarf Mistletoe Occurrence	0-1	2-2	2-2
Root Disease Occurrence	N/A	N/A	N/A
Bark Beetle Pressure	1-1	1-2	2-3
Crown Volume Scorch	0-0	1-1	2-3
Bole Scorch	0-0	0-0	0-9
Total Scorch Height	1-1	1-1	1-3
Duff Consumption	0-0	0-0	4-6
Totals	2-5	6-10	14-30

Factors Affecting Survival of Fire Injured Trees: A Rating System For Determining Relative Probability of Survival of Conifers in the Blue and Wallowa Mountains

AMENDMENT 2

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August 30, 2006

Report No. BMPMSC-03-01 Amend. 2

Summary of Changes:

This amendment documents changes to the parent document for ponderosa pines 21-inches dbh and larger. The parent document is Report No. BMPMSC-03-01 dated November 25, 2002. Specifically, this amendment makes these changes:

1. Temporarily suspends use of Part C of the current Rating System until it can be validated with long-term survivorship data.
2. Modifies Part B: **Ponderosa Pine (Mature and Overmature Trees >180 years old—Barrett 1979)**
3. Specifies the site of cambium sampling for the **Bole Scorch** Factor (Factor No. 8) of Part B of the Rating System for all ponderosa pines to be the recesses formed at the interstices between major lateral roots at the root crown or root-collar region, where cambium is afforded greater protection from heat generated by smoldering duff against the bole.
4. Changes the **Bole Scorch** Factor (Factor No. 8) to clarify terminology used and to specify distinctions between penalty criteria related to numbers of quadrants sampled with dead cambium.
5. Modifies diameter classes for **Crown Volume Scorch** (Factor 7) and **Total Scorch Height** (Factor 9) to more accurately estimate large ponderosa pine survival by 2-inch dbh classes.
6. Modifies **Suggested Decision Classes** for mature and overmature ponderosa pine in Part B. of Rating System.
7. Specifies use of Part B of Rating System: **Ponderosa Pine (Young and Immature Trees <180 years old—Barrett 1979)** for trees up to 26 in. dbh that are in the young "Black-Bark" or "Bull Pine" form, and specifies use of **Amendment 2** Part B: **Ponderosa Pine (Mature and Overmature Trees >180 years old—Barrett 1979)** for ponderosa pines 21 in. dbh and larger that are in the older "Yellow-Brown Bark" form.

Discussion:

There are two types of fire effects recognized in the published fire effects literature: First-order and Second-order fire effects. Reinhardt et al. (2001) defined these as follows. "*First-order fire effects are those that are the direct result of the combustion process such as plant injury and death, fuel consumption and smoke production.*" First-order fire effects occur at the time of the fire or shortly afterwards. "*Second-order fire effects are the indirect consequences of fire and other post-fire interactions such as weather.*" They may take place a few hours to years after a fire. Important second-order fire effects include vegetation succession, release of serotinous cones by lodgepole pine, and trees succumbing to insect or disease infestations (Jain 2004; Caratti et al. 2005).

The Rating System takes into account First-order fire effects as well as incorporating factors that, for many species and size classes of trees, help characterize conditions in which trees undergo delayed post-fire tree mortality due to Second-order fire effects; that is, the mortality that continues well beyond the time First-order fire effects should have been complete. This amendment includes First-order fire effects and short-term Second-order fire effects; primarily mortality likely to be caused by an endemic population of western pine beetle and woodborers being attracted to and killing trees severely damaged and stressed by fire.

Delayed tree mortality is a post-fire effect of growing concern, particularly in silvicultural efforts to restore historic stand conditions containing large, old trees that previously survived frequent, low-intensity, low-severity fire regimes (Arno 2000). The proportion of trees dying from First- and Second-order fire effects declines every year after the fire, but may extend out over a long period of time. Covington et al. (1997) observed that previous research near their study site showed prescribed burning resulted in high mortality of presettlement ponderosa pines (60 percent mortality over a 20-year period) and lethal soil temperatures under presettlement tree canopies (Covington and Sackett 1984, 1990, 1992; Harrington and Sackett 1990; Sackett et al. 1993) We have observed delayed mortality commonly occurring to large, mature and overmature ponderosa pines that were exposed to long-duration heating of roots and the root crown from smoldering combustion of deep accumulations of litter and duff at the base of these trees (Scott 2002). Published studies demonstrate that basal girdling and root injury are especially critical to initiating delayed mortality (Connaughton 1936; Herman 1954; Kaufmann and Covington 2001; McHugh and Kolb 2003; Rust 1933; Ryan and Amman 1996; Sackett and Haase 1998; Thomas and Agee 1986; Agee 2003). Hence, this amendment was prepared in an attempt to more accurately characterize large, old ponderosa pine survival after wildfire, as influenced by First-order and short-term Second-order fire effects.

While lethal First-order fire effects are immediate, or occur within a relatively short period of time after fire, those trees may not be readily recognized as being dead until two or possibly more years because the crowns may remain green. Crown symptoms of chlorotic to red foliage, though commonly recognized as being indicative of trees that are dying or dead, are often delayed in being expressed. While a tree requires live functioning roots, stem, and crown to remain alive, oftentimes, close inspection of recently fire-damaged trees will indicate that the roots or the stem of the tree have been killed while the crown (foliage) remains green. Crown fading will follow, but may be delayed depending on a variety of factors. A tree with the root system, stem, or crown lethally damaged, is a dead tree (Filip et al, *in press*; Schmitt and Filip 2005). Signs of stem mortality include deep charring completely encircling the circumference such that the phloem and cambium are girdled, or evidence of successful bark beetle colonization, also

extending completely around the circumference. Lethal root collar damage can be recognized by excessive or deep charring around the entire circumference at the base, with little or no remaining live cambium. The significance of these fire-induced injuries is affirmed by the fact that "*burning locally destroys the phloem tissue and thus cuts the pathways for translocating carbohydrates and nutrients towards the root system*" (Ducrey et al. 1996).

In the Rating System we have made a distinction between ponderosa pine younger than 180 years and ponderosa pine older than 180 years, and rate these trees for post-fire survivability differently. While in most cases, smaller pines will be younger trees, and trees larger than 21-inches dbh will be in the older age-class, there will be cases where mature, old pines are in the smallest (21-inch dbh class), and young pines that are growing on good sites and well-spaced, will be larger trees. Thus, the size classes can overlap, and the age distinction should be made on a stand basis, or between individual trees if they both occur in stands to be marked. These two age-classes are treated differently in our Rating System because of the likely differences in accumulated fuels between these groupings and the differences in potential damage when this material burns. Young, fast-growing pines normally have blackened deeply furrowed bark (Harlow and Harrar 1969) and have not yet developed the sloughing, plate-like bark. Sometimes, these trees are referred to as "bull," "Black-bark," or "blackjack" pines. The accumulated fuels around the bases of these trees are primarily cast needles. Older, slower-growing pines have the characteristic yellow-brown coloration and flattened surface of the bark. The dead outer bark of these older trees is comprised of a thick layer of plates that continually exfoliate and accumulate along with needles and other debris at the base of trees. Additionally, and in most cases, older trees and older stands have deeper accumulations of debris as a result of abbreviated recent fire periodicity and severity, and larger diameter trees have correspondingly more debris (Ryan and Frandsen 1991).

A number of formal and informal efforts at monitoring survival of large diameter ponderosa pines after wildfire and prescribed fire have been on-going in the Pacific Northwest and elsewhere for a number of years. During August 2006, we reviewed survival of large ponderosa pines 4 years and 10 years after fire on 2 different wildfires on the Malheur National Forest. Our observations revealed that delayed mortality of large, old ponderosa pines has not occurred at the rate projected by the current Rating System. Some large ponderosa pines that have been rated with the original procedures contained in Part B or Part C of the Rating System have survived 4 years, and some even up to 10 years, with 75% of the root quadrants containing dead cambium. We believe there are a number of reasons for longer-than-anticipated survival times for trees with sub-lethal injuries to roots, bole, and crown that are expected to undergo delayed mortality from Second-order fire effects: (1) basal sampling locations for the Bole Char factor (Factor 8) may be overestimating actual basal circumference with dead cambium; (2) epidemic insect populations have failed to develop within areas with numerous large-diameter root-injured trees; (3) drought has been moderated with good winter snow-packs containing high water content, and back-to-back "wet" springs with precipitation levels at or above normal precipitation have prevented moisture from becoming limited in trees with fire-induced root injuries; and (4) Larger trees having a greater range of variability of bark thickness, injury level, rooting habit and root-grafting potential, crown size and condition, etc., take longer to die resulting from changes in available moisture.

Accordingly, we do not believe that the current Rating System for Part C is refined enough at the present time to confidently rate trees having Low or Moderate probability to survive within any specified timeframe. There is broad variability of delayed mortality of trees rated under the present Part C of the Rating System, and that variability is influenced by moisture changes in growing seasons following the

fire, inconsistency in injuries from fire, site quality, size class, aspect, location, and insect populations and other factors that are unpredictable. For a few large ponderosa pines, delayed mortality may extend farther into the future than anticipated. For these trees, the duration of survival is imperfectly known and depends on many factors, some of which are largely unpredictable. Hence, we are temporarily withdrawing Part C from the Rating System until validation data supports its refinement and re-inclusion in the Rating System.

Given these issues, we believe it is necessary to review and refine Part B of the Rating System, specifically for mature and overmature ponderosa pines, and incorporate any needed changes. We have done that in preparing this amendment. First, we believe our training of marking crews to sample the cambium at the base of the tree by chopping through the bark to examine cambium near the root crown or on the main lateral roots may be providing overestimates of basal girdling since these sites are ones usually most exposed to heat from smoldering fire and most likely to contain fire-killed cambium. In this amendment, we are changing the location of cambial sampling for the **Bole Char Factor** (Factor No. 8) to the recesses formed at the interstices between major lateral roots, rather than on the roots themselves. Root crown or root-collar cambium tends to be protected from fire by thicker bark at these locations (Dickinson and Johnson 2001); hence, measurements of cambial survival or mortality for purposes of estimating the amount of circumference with basal girdling, will be more accurate if sampled at these locations.

In addition, we have attempted to improve accuracy in the Rating System with other changes in Part B for mature and overmature ponderosa pines, as included in this amendment. The changes in the Rating System covered in this amendment are based in large part on re-running the Behave Plus model (Andrews and Bevins 1999) using a data set for large-diameter ponderosa pines from the Blue Mountains (Malheur National Forest) to provide regression estimators for tree height based on diameter to use in the Behave Plus model. The Behave Plus model uses the Ryan and Reinhardt (1988) logistic regression equation and the bark thickness equations from Reinhardt et al.(1997) for different tree species, to compute probability of fire-induced tree mortality. Through these modeling runs, we have produced diameter classes for **Crown Volume Scorch** (Factor 7) and **Total Scorch Height** (Factor 9) to more accurately estimate large ponderosa pine survival by 2-inch dbh classes.

This amended Rating System should be used on larger ponderosa pines that are ≥21 inches in diameter. We provide rating criteria for 21-40 inch trees. Large trees ≥21 inches in diameter not included in this amended Rating System should use the nearest inch-class criteria to the tree being rated. For young and immature ponderosa pines up to roughly 26 inches in diameter, continue to use the original Rating System for these “black-bark” forms or size classes of ponderosa pines, as given in the original.

Thus, in this amendment we are specifying using Part B of the original Rating System for **Ponderosa Pine (Young and Immature Trees <180 years old—Barrett 1979)** for trees up to 26 in. dbh that are in the young “Black-Bark” or “Bull Pine” form, and specify using **Amendment 2** Part B: **Ponderosa Pine (Mature and Overmature Trees >180 years old—Barrett 1979)** for ponderosa pines 21 in. dbh and larger when these trees are in the older “Yellow-Brown Bark” form.

In this amendment, we have also modified the Rating System from the original by adjusting the distribution of rating scores for some of the criteria and the **Suggested Decision Classes**. Notably, we

have increased the penalty score for the **Bole Char Factor** (Factor No. 8) to reflect the significance of complete basal girdling to delayed mortality from Second-order fire effects.

Trees having High probability of survival are those that had non-lethal First-order fire effects and are unlikely to succumb to Second-order fire effects in the short term (2 to 3 years). These trees are identified in the Rating System as having a relatively low Composite Rating Score.

Trees having a Moderate probability of survival are those having been damaged by First-order fire effects where either the damage is sufficiently severe that tree mortality may result from injury to the roots, stem or crown (Ryan 1990; Schmitt and Filip 2004; Filip et al. *in press*), or where First-order fire effects are initially sub-lethal, but mortality from Second-order fire effects may result from insect attack, where trees are killed by a resident endemic population of western pine beetles or woodborers due to fire-induced damage and stress in the short-term (2 to 3 years). These trees have a Composite Rating Score that falls between the High probability and Low probability for survival. There is a lower certainty of survival or morality of trees in this class, scoring in the gray area between the trees likely to live and likely to die. We envision roughly half the trees falling within this category will die while roughly half will remain alive over the several years following the fire based on Ryan's statement "*in the absence of significant crown injury, most trees survive up to 25% basal girdling, but few trees survive more than 75%. Between these ranges about one-half of the trees survive*" (Ryan 1990). Trees identified as having a Moderate probability of survival have midrange Composite Rating Scores.

Trees having Low probability of survival are those that have been damaged by lethal First-order fire effects, or sufficiently injured that they are susceptible and highly likely to be affected by Second-order fire effects; killed by the resident endemic population of western pine beetles or woodborers in the short-term (2 to 3 years). It is expected that the large majority of trees that do die as a result of the fire will die within this timeframe. These trees are identified in the Rating System as having a relatively high Composite Rating Score.

Tree scoring in this Rating System has a variety of possible scenarios, and the probability of tree survival decreases with increasing Composite Rating Scores, even within the three individual Decision Classes. In addition, this Rating System may not fully account for interactions between different fire-caused injuries, some of which may combine to exacerbate mortality rates (Ryan 1990). In view of this, the Rating System will provide more liberal estimates of probable tree survival. Although the divisions between the Suggested Decision Classes are based on common outcomes of the likely conditions encountered after fire, these classes are not absolute. For example, it is possible for a tree to have lethal root collar damage (essentially 100% of the circumference girdled at the base), and by definition be dead (see Filip et al. *in press*; and Schmitt and Filip 2005), but the tree may rate out into the Moderate survival category, especially if the remaining portions of the tree experienced little or no visible damage. Another similar example would be a tree that had complete lethal crown volume scorch—again a dead tree—but, without lower bole or root-collar char. Trees that are rated using this system and fall into the Moderate survival probability class should be evaluated, particularly, for presence of the critical factors that determine tree survival such as live cambium at the root collar, or a viable live crown.

We believe the modified Rating System contained in this amendment provides refinements that reflect more accurate determinations of tree survival than the original Rating System contained in Part B for Mature and Overmature Ponderosa Pine. Moreover, we believe this modification of the Rating System

offers a conservative approach to salvage marking and will result in the retention of greater numbers of large-diameter, mature and overmature ponderosa pines that may survive non-lethal First-order fire effects, and may not experience Second-order fire effects. Hence, this modification is consistent with Forest Service policy and the purpose of the Eastside Wildlife Screens: to preserve living old-growth forest for wildlife needs.

Part B. Factors for Determining Tree Survival up to 1 Year After Fire:

(Instructions: Assign the appropriate rating value in parentheses to each factor below, then subtotal score)

Ponderosa Pine *(Trees ≥ 21 in. dbh; usually >180 years old—Barrett 1979)*

(Use nearest diameter below to diameter of tree being evaluated)

FACTOR **RATING**

7. **Crown Volume Scorch** (Reinhardt and Ryan 1988; assumes 50% pre-fire live crown ratio)

a. No visible scorching (0)

f. For trees **21 in.** dbh :
Crown volume scorched between 1-67% (mortality probability 6-41%) (1)
Crown volume scorched between 68-85% (mortality probability 42-75%) (2)
Crown volume scorched between 86-100% (mortality probability 76-93%) (3)

g. For trees **24 in.** dbh :
Crown volume scorched between 1-71% (mortality probability 5-41%) (1)
Crown volume scorched between 72-88% (mortality probability 42-75%) (2)
Crown volume scorched between 89-100% (mortality probability 76-91%) (3)

h. For trees **26 in.** dbh :
Crown volume scorched between 1-73% (mortality probability 4-42%) (1)
Crown volume scorched between 74-90% (mortality probability 43-76%) (2)
Crown volume scorched between 91-100% (mortality probability 77-89%) (3)

i. For trees **28 in.** dbh :
Crown volume scorched between 1-74% (mortality probability 3-39%) (1)
Crown volume scorched between 75-91% (mortality probability 40-75%) (2)
Crown volume scorched between 91-100% (mortality probability 76-88%) (3)

j. For trees **30 in.** dbh :
Crown volume scorched between 1-76% (mortality probability 3-40%) (1)
Crown volume scorched between 77-93% (mortality probability 41-75%) (2)
Crown volume scorched between 94-100% (mortality probability 76-87%) (3)

k. For trees **32 in.** dbh :
Crown volume scorched between 1-78% (mortality probability 3-41%) (1)
Crown volume scorched between 79-94% (mortality probability 42-76%) (2)
Crown volume scorched between 95-100% (mortality probability 77-85%) (3)

l. For trees **34 in.** dbh :
Crown volume scorched between 1-78% (mortality probability 2-39%) (1)
Crown volume scorched between 79-94% (mortality probability 40-75%) (2)
Crown volume scorched between 95-100% (mortality probability 76-84%) (3)

m. For trees **36 in.** dbh :
Crown volume scorched between 1-79% (mortality probability 2-40%) (1)
Crown volume scorched between 80-95% (mortality probability 41-75%) (2)
Crown volume scorched between 96-100% (mortality probability 76-83%) (3)

f. For trees **38 in.** dbh :
Crown volume scorched between 1-81% (mortality probability 2-41%) (1)
Crown volume scorched between 82-96% (mortality probability 42-75%) (2)
Crown volume scorched between 97-100% (mortality probability 76-82%) (3)

g. For trees ≥ **40 in.** dbh :
Crown volume scorched between 1-81% (mortality probability 2-40%) (1)
Crown volume scorched between 82-97% (mortality probability 41-75%) (2)
Crown volume scorched between 98-100% (mortality probability 76-81%) (3)

10. **Bole Char at Ground Level** (Ryan 1990; Ryan and Frandsen 1991; Wagener 1961; Schmitt and Spiegel 2002)
(*To ensure accurate interpretation of the following criteria, the cambium at the root collar should be sampled from 4 areas of equally spaced quadrants from around the bole on all trees in the recesses between the main lateral roots (do not sample on the roots themselves). The numbers enclosed in parentheses following the bole scorch or char criteria are the numbers of sampled quadrants with* ***dead*** *cambium out of the 4 quadrants sampled*)

a. Bole scorching (blackening of the bole with no change in bark structure) (0)
absent or light, with no bark consumption at the root collar and/or lower stem. Phloem and cambium not fire-killed.

b. ≤75% circumference of the bole cambium and phloem at the root collar is (2)
dead (i.e., **1-3 quadrants with dead cambium**); bole scorch, and bark consumption and char (any alteration of bark thickness and visibly changed bark structure) at the root collar and/or lower stem has occurred and may have killed most, but not all, of the cambium at the root collar. Cambium on the upper surfaces of the main lateral roots adjacent to the bole may be dead. Sampling cambium and phloem at 4 sites around the root collar in the recesses between the main and lateral roots (do not sample on the roots themselves) indicates that at least 25% of the circumference at the root collar is alive. If marking is delayed more than 1 year after the fire, other indicators such as woodpeckers and bark beetles may indicate a portion of killed root collar or bole circumference. A tree characterized with these conditions can be expected to survive for the short-term if other factors have not contributed lethal effects.

c. >75% circumference of the bole cambium and phloem at the root collar is (6)
dead (**4 quadrants with dead cambium**); bole scorch and bark consumption at the root collar and/or lower stem is extreme, with bark consumption occurring around the entire root collar and/or lower stem. Sampling the cambium at 4 sites around the root collar in the recesses between the main

lateral roots indicates that less than 25% of the circumference at the root collar is alive. A tree characterized with these conditions is not expected to survive, having evidence of lethal root and/or bole damage, even though the crown may remain green for the short-term.

10. **Total Scorch Height** (Reinhardt and Ryan 1988; Ryan and Reinhardt 1988)
(Use nearest diameter below to diameter of tree being evaluated)

a. No visible scorching (0)

f. For trees **21 in.** dbh :
Total scorch height between 1-74 ft. (mortality probability 6-41%) (1)
Total scorch height between 75-84 ft. (mortality probability 42-75%) (2)
Total scorch height between 85-104 ft. (mortality probability 76-93%) (3)

g. For trees **24 in.** dbh :
Total scorch height between 1-81 ft. (mortality probability 5-41%) (1)
Total scorch height between 82-92 ft. (mortality probability 42-75%) (2)
Total scorch height between 93-111 ft. (mortality probability 76-91%) (3)

h. For trees **26 in.** dbh :
Total scorch height between 1-86 ft. (mortality probability 4-42%) (1)
Total scorch height between 87-98 ft. (mortality probability 43-76%) (2)
Total scorch height between 99-116 ft. (mortality probability 77-89%) (3)

i. For trees **28 in.** dbh :
Total scorch height between 1-90 ft. (mortality probability 3-39%) (1)
Total scorch height between 91-103 ft. (mortality probability 40-75%) (2)
Total scorch height between 104-121 ft. (mortality probability 76-88%) (3)

j. For trees **30 in.** dbh :
Total scorch height between 1-95 ft. (mortality probability 3-40%) (1)
Total scorch height between 96-109 ft. (mortality probability 41-75%) (2)
Total scorch height between 110-126 ft. (mortality probability 76-87%) (3)

k. For trees **32 in.** dbh :
Total scorch height between 1-100 ft. (mortality probability 3-41%) (1)
Total scorch height between 101-115 ft. (mortality probability 42-76%) (2)
Total scorch height between 116-131 ft. (mortality probability 77-85%) (3)

l. For trees **34 in.** dbh :
Total scorch height between 1-104 ft. (mortality probability 2-39%) (1)
Total scorch height between 105-120 ft. (mortality probability 40-75%) (2)
Total scorch height between 121-136 ft. (mortality probability 76-84%) (3)

m. For trees **36 in.** dbh :
Total scorch height between 1-109 ft. (mortality probability 2-40%) (1)

Total scorch height between 110-126 ft. (mortality probability 41-75%) (2)
Total scorch height between 127-141 ft. (mortality probability 76-83%) (3)

f. For trees **38 in.** dbh :
Total scorch height between 1-114 ft. (mortality probability 2-41%) (1)
Total scorch height between 115-132 ft. (mortality probability 42-75%) (2)
Total scorch height between 133-146 ft. (mortality probability 76-82%) (3)

g. For trees ≥ **40 in.** dbh :
Total scorch height between 1-118 ft. (mortality probability 2-40%) (1)
Total scorch height between 119-137 ft. (mortality probability 41-75%) (2)
Total scorch height between 138-151 ft. (mortality probability 76-81%) (3)

10. **Duff Consumption** (Ryan 1990; Ryan and Frandsen 1991; Ryan and Noste 1985)
a. No leaf litter or duff scorched or consumed (0)
b. Leaf litter charred or consumed; upper duff charred, but not altered over entire depth. (1)
c. Leaf litter consumed; duff deeply charred or consumed, but underlying mineral soil is not visibly altered. (2)
d. Litter and duff completely consumed, and top layer of mineral soil visibly altered, often reddish. (3)

Subtotal Rating Score for Part B: _____

Composite Rating Score Part A+B: _____

Suggested Decision Classes:

(Refer to Rating Range Determinations Below)

Large Diameter Ponderosa Pines

High Probability of Tree Surviving = Composite Rating Score Ranging from **1-7**
Moderate Probability of Tree Surviving = Composite Rating Score Ranging from **8-15**
Low Probability of Tree Surviving = Composite Rating Score Ranging from **16-24**

Rating Range Determinations for Ponderosa Pines

(High, Moderate, and Low Survival Up To One Year After Fire)

	Composite Rating Ranges By Survival Decision Classes		
	High	**Moderate**	**Low**
Season of Fire	0-2	1-2	1-2
Pre-Fire Vigor, Growth Rate, and Site Quality	0-0	0-1	1-1
Arrangement/Distribution of Down Woody Material	0-0	0-1	1-1
Dwarf Mistletoe Occurrence	0-1	0-2	0-2
Root Disease Occurrence	NA	NA	NA
Bark Beetle Pressure	1-1	2-2	2-3
Crown Volume Scorch	0-0	1-1	2-3
Bole Scorch	0-2	2-2	6-6
Total Scorch Height	0-0	1-2	1-3
Duff Consumption	0-1	1-2	2-3
Totals	1-7	8-15	16-24

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